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## Battling Smog: A Plan for Action

by Kenneth Chilton and Anne Sholtz



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## 1. INTRODUCTION

Nearly eight years late, amendments to the Clean Air Act appear likely to be passed by the 101st Congress and signed into law by President George Bush. The following analysis of atmospheric ozone (smog) and the current and proposed methods of dealing with this pollutant is intended to provide a perspective that is largely missing from the current debate.

Thus far, most of the public discussion of Clean Air Act proposals, and of related issues such as the South Coast Air Quality Management District's plans for Los Angeles and environs, has focused on specific control measures for attaining the ozone standard prescribed in the Act. For the most part, the public debate is uninformed. Few citizens know the true health risks associated with ozone, their exposure to "unhealthful" levels of the pollutant, or the costs and benefits of the current approach to reducing smog.

This study seeks to provide a wider perspective by answering the following basic questions:

- What does it mean to be a nonattainment area?
- What are the health and other effects of ozone pollution?
- What causes ozone buildup?
- What are the costs and benefits of "getting there" -- reaching the air quality standard?
- Why has progress been so slow?
- How do the leading bills in Congress propose to deal with the problem of urban smog?
- How can the Clean Air Act be changed to protect public health and welfare in a more economical way?

The following sections of the report tackle these issues in the order presented above.

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Kenneth Chilton is Associate Director of the Center for the Study of American Business at Washington University in St. Louis. Anne Sholtz is the Arthur and Jeanne Ansehl Fellow at the Center. Opinions expressed by the authors are personal.

## 2. WHAT DOES IT MEAN TO BE A NONATTAINMENT AREA?

An area is considered to be "nonattainment" for ozone if the fourth highest daily monitor reading taken during the most recent three-year period registers an ozone concentration above 0.12 parts per million (ppm) for more than one hour. (The fourth highest daily maximum reading is referred to as the "design value.") The definition is very cut and dried, taking no account of other monitor readings in a city, which may be far less than the highest monitor reading.

According to the most recent Environmental Protection Agency (EPA) figures, 88.6 million Americans live in counties that exceeded the ozone standard in 1987.<sup>1</sup> Table 2.1 is a partial list of the areas that are "nonattainment." (The table is in the order of the severity of the ozone problem -- in "design value" order. A complete list is presented in the appendix Table A-3.1.)

The final column of Table 2.1 indicates how much emissions of volatile organic compounds (a prime ingredient of ozone) must be reduced for a particular area to reach the 0.12 parts per million standard. Details of this table will be discussed in other sections of this report but one point is abundantly clear: many cities need to make large reductions in volatile organic compounds (VOCs) to reach attainment. More than 63 million Americans live in areas where VOCs will need to be reduced by 40 percent or more to meet the standard.

The term "volatile organic compound" and its abbreviation, "VOC," will be used throughout the study. In simple terms, VOCs are sources of reactive hydrocarbons from man-made sources such as gasoline, solvents, paints, etc. and natural sources such as decaying vegetation which produces methane. These compounds are "volatile," meaning easily vaporized and "organic," containing carbon.

But the designation of an area as nonattainment is misleading. This definition focuses on a one-hour peak concentration figure in order to provide an adequate margin of safety against *any* adverse health effects. But this is not necessarily the best measure of air quality.

In addition, categorizing areas as simply attainment or nonattainment gives little indication of normal air quality. Citing the number of exceedances (the number of days that ozone concentrations are



Table 2.1

**NONATTAINMENT AREAS MORE THAN 25 PERCENT  
ABOVE STANDARD**

| Area                                    | Population<br>(millions) | 1986<br>-1988<br>design<br>value | Percent<br>above<br>standard | NMOC/<br>NO <sub>x</sub><br>ratio | Required<br>VOC<br>reductions<br>(%) |
|-----------------------------------------|--------------------------|----------------------------------|------------------------------|-----------------------------------|--------------------------------------|
| Los Angeles, CA                         | 8.3                      | .34                              | 183%                         | 10.4                              | 80%                                  |
| New York City, NY                       | 8.5                      | .22                              | 83%                          | 11.7                              | 67                                   |
| Chicago, IL                             | 6.2                      | .20                              | 67%                          | 7.8                               | 53                                   |
| Houston, TX                             | 3.2                      | .19                              | 58%                          | 10.9                              | 60                                   |
| Baltimore, MD                           | 2.9                      | .18                              | 50%                          | 7.1                               | 42                                   |
| Hartford, CT                            | 0.7                      | .18                              |                              | 9.4                               | 53                                   |
| Milwaukee, WI                           | 1.4                      | .18                              |                              | 9.6                               | 53                                   |
| Muskegon, MI                            | 0.2                      | .18                              |                              | 12.2                              | 61                                   |
| Philadelphia, PA                        | 4.5                      | .18                              |                              | 7.2                               | 43                                   |
| Portsmouth-Dover,<br>NH-ME <sup>1</sup> | 0.2                      | .18                              |                              | 12.2                              | 38                                   |
| San Diego, CA                           | 2.4                      | .18                              |                              | 7.4                               | 44                                   |
| Atlanta, GA                             | 2.6                      | .17                              | 42%                          | 6.5                               | 36                                   |
| Boston, MA <sup>1</sup>                 | 2.8                      | .17                              |                              | 5.7                               | 34                                   |
| El Paso, TX                             | 0.6                      | .17                              |                              | 8.5                               | 46                                   |
| Fresno, CA                              | 0.6                      | .17                              |                              | 12.2                              | 55                                   |
| Huntington-Ashland,<br>WV-KY            | 0.3                      | .17                              |                              | 12.2                              | 58                                   |
| Louisville, KY                          | 1.0                      | .17                              |                              | 12.2                              | 58                                   |
| Parkersburg-Marietta,<br>WV-OH          | 0.2                      | .17                              |                              | 12.2                              | 58                                   |
| Sheboygan, WI                           | 0.1                      | .17                              |                              | 12.2                              | 58                                   |
| Worcester, MA                           | 0.4                      | .17                              |                              | 12.2                              | 58                                   |
| Bakersfield, CA                         | 0.5                      | .16                              | 33%                          | 12.2                              | 49                                   |
| Baton Rouge, LA                         | 0.5                      | .16                              |                              | 14.8                              | 60                                   |
| Beaumont and<br>Port Arthur, TX         | 0.4                      | .16                              |                              | 22.4                              | 72                                   |
| Cincinnati, OH                          | 1.4                      | .16                              |                              | 9.1                               | 44                                   |



Table 2.1 (continued)

| Area                 | Population<br>(millions) | 1986<br>-1988<br>design<br>value | Percent<br>above<br>standard | NMOC/<br>NO <sub>x</sub><br>ratio | Required<br>VOC<br>reductions<br>(%) |
|----------------------|--------------------------|----------------------------------|------------------------------|-----------------------------------|--------------------------------------|
| Dallas-Ft. Worth, TX | 2.4                      | .16                              | 33%                          | 9.1                               | 44                                   |
| Portland, ME         | 0.2                      | .16                              |                              | 11.6                              | 52                                   |
| Providence, RI       | 0.6                      | .16                              |                              | 12.2                              | 54                                   |
| Sacramento, CA       | 1.3                      | .16                              |                              | 9.6                               | 45                                   |
| Springfield, MA      | 0.2                      | .16                              |                              | 12.2                              | 53                                   |
| St. Louis, MO        | 2.4                      | .16                              |                              | 10.7                              | 50                                   |
| Washington, D.C.     | 3.6                      | .16                              |                              | 9.2                               | 45                                   |

<sup>1</sup> Transport emissions are included in calculations of required reductions.

*Source:* Population figures are from EPA, *National Air Quality and Emissions Trends Report, 1987*, Table 4-3. Design values, are from the July 27, 1989 EPA *Environmental News*. NMOC/NO<sub>x</sub> ratios and information needed to calculate percentage reductions are taken from a personal correspondence from Francis Bunyard, EPA Office of Air Quality Planning and Standards, August 1989.

above 0.12 ppm for more than one hour) provides a bit more information but also presents a jaundiced perspective of the problem's severity.

For example, Los Angeles undoubtedly suffers from the worst smog problem in the United States. L.A.'s design value is 0.34 ppm, nearly three times the air quality standard. Area ozone levels at the highest monitor exceeded 0.12 ppm for one hour or more, an average of 145 days a year during the period 1986-1988.<sup>2</sup>

But a different picture of the Los Angeles ozone problem forms, based on an alternative set of facts. The highest monitor reading was above the standard less than six percent of the total monitor hours in the five-year period 1981-1985. The reading at the highest monitor was above 0.24 ppm less than one-half of one percent of the total hours monitored at that site during this five-year period.<sup>3</sup>

Indeed, Los Angeles is not an isolated example. Table 2.2 lists the percent of monitor hours that air quality is at or below the 0.12 ppm standard for *all* monitor hours in an area. Using this slightly different measure, most Los Angeles residents breathe air that

Table 2.2

**MONITOR HOURS ABOVE AND BELOW  
OZONE STANDARD FOR SELECTED CITIES, 1981-1985**  
(percent of monitored hours)

| Area                                | Above<br>0.12 ppm | At or Below<br>0.12 ppm |
|-------------------------------------|-------------------|-------------------------|
| Los Angeles, CA                     | 2.67%             | 97.33%                  |
| Houston, TX                         | .53               | 99.47                   |
| Atlanta City, NJ                    | .49               | 99.51                   |
| New York, NY                        | .36               | 99.64                   |
| Providence, RI                      | .33               | 99.67                   |
| Portland, ME                        | .31               | 99.69                   |
| Atlanta, GA                         | .30               | 99.70                   |
| Dallas, TX                          | .17               | 99.83                   |
| Denver, CO                          | .10               | 99.90                   |
| Washington, DC                      | .10               | 99.90                   |
| Boston, MA                          | .08               | 99.92                   |
| Allentown, PA                       | .05               | 99.95                   |
| Baton Rouge, LA                     | .04               | 99.96                   |
| Portsmouth, Dover,<br>Rochester, NH | .04               | 99.96                   |
| Memphis, TN                         | .04               | 99.96                   |
| Richmond, VA                        | .04               | 99.96                   |
| Detroit, MI                         | .04               | 99.96                   |
| Cincinnati, OH                      | .03               | 99.97                   |
| Indianapolis, IN                    | .02               | 99.98                   |
| Kansas City, MO                     | .02               | 99.98                   |
| Portland, OR                        | .02               | 99.98                   |
| Tampa, FL                           | .02               | 99.98                   |

*Source: Ozone Concentration Data, American Petroleum Institute, May 1987, and Data on Ozone Concentrations, American Petroleum Institute, 1987.*

meets ozone standards 97.3 percent of the time. If this measure is applied to all other nonattainment areas, these cities meet or better the ozone standard more than 99.4 percent of the time.

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*Equating the term "nonattainment" with unhealthful  
is an oversimplification.*

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The point is that equating the term "nonattainment" with unhealthful is an oversimplification. Without knowledge of the health effects of ozone and a more realistic perspective of the numbers of individuals exposed to elevated ozone levels and the frequency and duration of that exposure, the general public is presented with a distorted view of America's smog difficulties.

### 3. EFFECTS AND CAUSES OF SMOG

In spite of extensive research, the effects of ozone on human health and vegetation remain the subject of considerable debate. In addition, the chemistry of smog is not understood particularly well. The following description of ozone's effects and causes summarizes much of what is known about ozone and what uncertainty remains.

#### **Health Effects of Ozone**

Health effects of ozone have been studied extensively during the past two decades. Both short-term (acute) effects and long-term (chronic) effects have been examined, but by far the greatest amount of research has been on acute responses to elevated levels of ozone.

Medical research has used two basic types of studies -- epidemiological and clinical. Epidemiological research on pollutants usually examines hospital and doctor records to determine if there is a relationship between a given health effect and some environmental factor such as elevated ozone levels. Clinical studies, on the other hand, are conducted in controlled settings where the environment experienced by the subject is under the researchers' control.

**Epidemiological Studies.** Epidemiological studies are the best source of information on the chronic health effects of ozone on humans because attempting to clinically induce long-term, debilitating effects on human subjects is clearly unacceptable. However, a variety of confounding variables and lack of information on individuals' exposures to ozone have typically made it difficult to obtain strong results from these studies. Consequently, the extent of ozone's chronic effects on humans has not been clearly demonstrated.<sup>4</sup>

Similar problems, particularly lack of information on exposure, plague analyses of epidemiological data for purposes of determining acute health effects. Indeed, the Environmental Protection Agency's (EPA) vast, five volume report *Air Quality Criteria for Ozone and Other Photochemical Oxidants*, released in August of 1986, concludes:

Reported effects on the incidence of acute respiratory illness and on physician, emergency room, and hospital visits are not clearly related with acute exposure to ambient ozone or oxidants and, therefore, are not useful for deriving health effects criteria for standard-setting purposes. Likewise, no convincing association has been demonstrated between daily mortality and daily oxidant concentrations; rather, the effect correlates most closely with elevated temperatures.<sup>5</sup>

**Clinical Studies.** Clinical studies provide the other source of information on the health effects of ozone on humans. These



studies have been criticized because they typically use small numbers of subjects who have not been randomly selected. Not all clinical studies are small-scale, however.

For example, McDonnell et al studied 135 subjects -- healthy, young, adult men who lived in low-pollution areas.<sup>6</sup> The test group was segmented into six subgroups, and each subgroup was exposed to one of six concentrations of ozone (0.12, 0.18, 0.24, 0.30, and 0.40 ppm) while exercising very heavily, but intermittently, for two hours. Small changes in breathing capacity were observed at 0.12 and 0.18 ppm. Only at the higher levels were average lung function losses greater than 10 percent.

Although average lung function losses were mild even at the 0.18 level, individual responses varied greatly -- and some subjects experienced severe decreases in lung function while others experienced no decreases whatsoever. These widely varying responses to ozone by seemingly healthy adults may partially be explained by the individuals' breathing patterns (quick and shallow versus slow but deep) and modes (oral versus nasal). But for the most part, some still unidentified individual intrinsic factor seems to be responsible for these differences.<sup>7</sup>

It would be impossible to summarize the results of the myriad of clinical studies that have been conducted, but there are a few points that often seem to go unnoticed. For instance, not all symptoms commonly associated with ozone exposure are actually attributable to this pollutant. Ozone, in and of itself, does not cause eye irritation. In clinical studies where the concentration of ozone is several times higher than any likely to be encountered in ambient air, no eye irritation was experienced.<sup>8</sup> Researchers in this field believe that it is more likely that this problem is caused by other oxidants such as aldehydes.

Ozone's effects on pulmonary function appear to involve an attenuation response, albeit a *temporary* one. Results from clinical studies show that, with repeated exposure to ozone, reductions in pulmonary function are greatest on the second day. On each succeeding day, the reductions are less than the day before. On the fifth exposure day small reductions or no changes are observed. Attenuation of a symptomatic response at a given ozone concentration does not reduce response to higher levels, however.<sup>9</sup> Following a sequence of repeated daily exposures, pulmonary function apparently returns to that prior to exposure within three to seven days.<sup>10</sup> This helps to explain why, in a clinical study of equal short-term exposures to ozone by Canadians and by people from Los Angeles, Canadians were more severely affected.<sup>11</sup>

Many of the concerns about ozone's effects on persons suffering



from lung disease also lack substantiation. There have been no consistent findings of symptom aggravation or changes in lung function in patients with chronic lung diseases other than asthma.<sup>12</sup> Also, according to available evidence, people with pre-existing lung disease respond to ozone exposure in a similar way as normal, healthy subjects.<sup>13</sup> There is also evidence that smokers are less responsive to ozone than nonsmokers.<sup>14</sup>

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*Many of the concerns about ozone's effects on persons suffering from lung disease lack substantiation.*

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Even the effects on asthmatics appear less severe than thought to be when the National Ambient Air Quality Standard was first established for ozone. One recent study showed no decrease in pulmonary function in adult asthmatics either at rest or with light exercise at ozone levels of 0.25 ppm.<sup>15</sup> Adolescent asthmatics were observed for one hour at exposures of 0.12 ppm and no change in pulmonary function was found.<sup>16</sup> Several other studies have shown that the increase in reported symptoms for asthmatics is statistically insignificant.<sup>17</sup> Due to concern for the subjects, asthmatics were not exposed to higher concentrations of ozone and higher exercise levels.

The results of laboratory tests are by no means definitive. But, in general, it appears that asthmatics react basically the same way to ozone exposure as non-asthmatics at moderate ozone concentrations and exercise levels.<sup>18</sup> This is not to imply, however, that persons with already reduced lung function are not more at risk when experiencing the same *incremental* loss of breathing capacity as healthy subjects.

There also has been some concern that ozone could affect human chromosomes. Although alterations in chromosomes have been observed in hamsters exposed to 0.20 ppm ozone,<sup>19</sup> no consistent changes have been demonstrated in human subjects at concentrations as high as 0.60 ppm.<sup>20</sup>

These underreported facts about the health effects of smog notwithstanding, clinical studies of ozone do show measurable and statistically significant short-term changes in lung function and increased respiratory symptoms. These changes are especially affected by "minute ventilation" -- frequency and depth of breathing -- which increases as exercise work load increases. Exercise increases the overall volume of ozone inhaled and also leads to a higher concentration of the pollutant in lung regions most sensitive to ozone.<sup>21</sup>

Table 3.1

**CLASSES OF INDIVIDUAL PHYSIOLOGICAL  
RESPONSE TO ACUTE OZONE EXPOSURE**

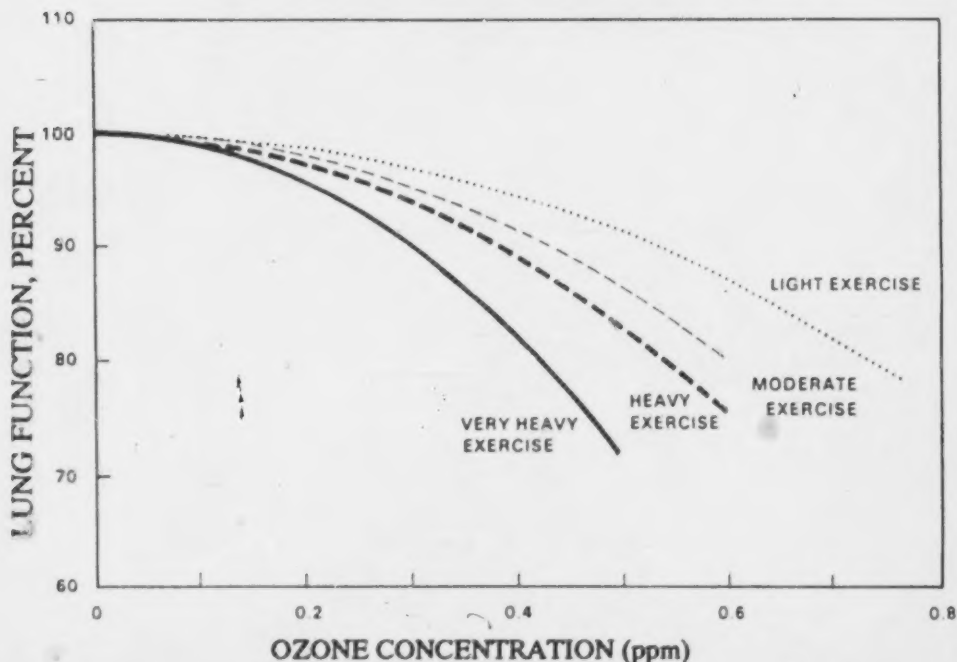
|                                                      | <u>Gradation of Response</u>     |                                                                        |                                                                                                      |                                                                                |
|------------------------------------------------------|----------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
|                                                      | Mild                             | Moderate                                                               | Severe                                                                                               | Incapacitating                                                                 |
| <b>Airway obstruction or lung function decrement</b> | 5-10%                            | 10-20%                                                                 | 20-40%                                                                                               | > 40%                                                                          |
| <b>Duration of effect</b>                            | Complete recovery in <30 minutes | Complete recovery in <6 hours                                          | Complete recovery in 24 hours                                                                        | Recovery in > 24 hours                                                         |
| <b>Symptoms</b>                                      | Mild to moderate cough           | Mild to moderate cough, pain on deep inhaling, and shortness of breath | Repeated cough, moderate to severe pain on deep inhaling and shortness of breath; breathing distress | Severe cough, pain on deep inhaling, and shortness of breath; obvious distress |
| <b>Limitation of activity</b>                        | None                             | Few individuals choose to discontinue activity                         | Some individuals choose to discontinue activity                                                      | Many individuals choose to discontinue activity                                |

*Source: Review of the National Ambient Air Quality Standards for Ozone and Other Photochemical Oxidants (Washington, D.C.: Office of Air Quality Planning and Standards, November 1987), p. VII-45.*

Table 3.1 describes the differences in response to acute ozone exposure. The Clean Air Scientific Advisory Committee recommends that "responses identified as 'mild' for individual response to ozone *not* be considered an adverse respiratory health effect, . . . (and) probably would not be considered medically significant and should not interfere with normal activity of most individuals."<sup>22</sup>

Figure 3.1

### LUNG FUNCTION DECREMENTS FOR VARYING OZONE AND EXERCISE LEVELS



Note: Lung function is measured as the volume of air a subject can force from his/her lungs in one second.

Source: *Air Quality Criteria for Ozone and Other Photochemical Oxidants*, Vol. I (Washington, D.C.: U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office, August 1988), p. 1-158.

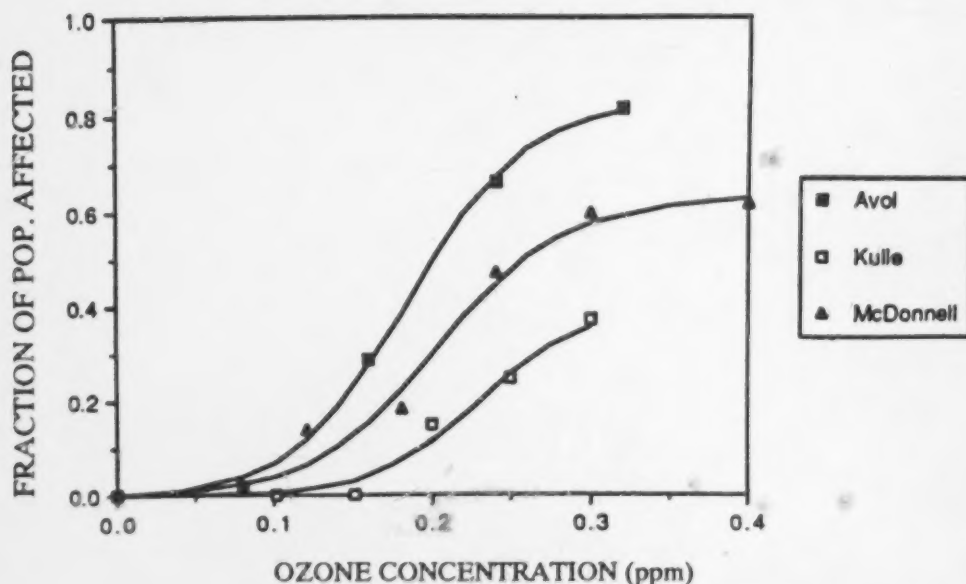
EPA has pooled a variety of controlled human exposure and field studies to estimate the relationship of exercise levels and ozone concentrations to decrements in forced expiratory volume and flow. Figure 3.1 illustrates EPA's findings for healthy adult subjects (18 to 45 years old) after one to three hours of exposure.

These overall results show less than a 10 percent loss in lung function at ozone levels more than four times the current ozone standard during light exercise. Even during very heavy exercise pulmonary function is typically reduced by less than 10 percent at concentrations twice the 0.12 ppm standard.

The EPA is quick to point out, however, that losses in lung function can occur with very heavy exercise in healthy adults at 0.15 to 0.16 parts per million and effects have been shown for some healthy

Figure 3.2

**FRACTION OF A HEAVILY EXERCISING POPULATION  
EXPERIENCING GREATER THAN A 10 PERCENT CHANGE  
IN LUNG FUNCTION DUE TO VARIOUS OZONE LEVELS**



Note: Exposures were for 1-hour continuous exercise for the Avol et al study and for 2 hours intermittent exercise for McDonnell et al and Kulle et al.

Source: *Review of the National Ambient Air Quality Standards for Ozone and Other Photochemical Oxidants* (Washington, D.C.: Office of Air Quality Planning and Standards, November, 1987), p. VII-10.

adults at levels as low as 0.12 ppm. Children also may show decreases in lung function at levels as low as 0.12 ppm with heavy exercise.<sup>23</sup>

EPA cautions that "average" response masks important individual sensitivity to ozone. Approximately 5 to 20 percent of the populations studied in these clinical tests have been dubbed "responders," showing a greater responsiveness than average subjects to the same conditions.

Figure 3.2 illustrates the fraction of the heavily exercising population experiencing at least a 10 percent decrease in lung capacity function (measured as decreases in the volume of air able to be exhaled by an individual during a one second interval) at various ozone levels. Three different studies are shown -- Avol et al, Kulle et al, and McDonnell.



One important factor for consideration is the sex of the studies' participants. Both McDonnell and Kulle include only men in their studies, while Avol includes men and women.<sup>24</sup> Although the studies including women are limited and, therefore, definitive conclusions cannot be drawn, "results of [four] studies suggest that lung function of women may be affected more than that of men for similar ozone exposures and exercise levels."<sup>25</sup> More investigation is needed in this area particularly because Avol's study involved continuous exercise for one hour, whereas McDonnell and Kulle's subjects exercised intermittently over a two-hour period.

The more general result from the McDonnell and Kulle studies is that about one in ten people (males) experience more than mild effects from ozone concentrations as low as 0.15 ppm while performing intermittent heavy exercise. The Office of Air Quality Planning and Standards in the EPA recommends that a mild physiological response (see Table 3.1) "not be considered an adverse respiratory health effect."<sup>26</sup> Thus only a small fraction of healthy adults experience adverse lung function decrements at levels 25 percent above standard when doing intermittent heavy exercise.

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*What is a "statistically significant" decrement in pulmonary function may not be a "significant health effect."*

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In addition, the EPA's analysis of these clinical studies also points out that a "statistically significant" decrement in pulmonary function may not be a "significant health effect." The 1986 EPA study states, "At the lower concentrations (0.12 to 0.15 ppm), the average changes in lung function are generally small (less than 5 percent) and are a matter of controversy in regard to their medical significance."<sup>27</sup>

Despite the extensive clinical and epidemiological studies done thus far, the book on ozone health effects is far from closed. Studies done on animals, for example, continue to raise concerns among medical researchers. Some animal research has indicated that ozone affects the lung's ability to resist bacterial and viral infections and accelerates the lung's aging process.<sup>28</sup> Extrapolating these findings to humans is highly problematic, however.

Further, a recent study on 10 men exposed to ozone concentrations of 0.12 ppm who moderately exercised for 6-3/4 hours showed that lung function losses increased as exposure progressed. Five subjects showed pulmonary losses of less than 10 percent (including two who showed no response); five showed decrements greater than 10 percent (including one subject whose loss was greater than 40



percent).<sup>29</sup> This study has raised the issue of whether a longer-term standard (for example, a six-hour standard) might be needed. Senate bill S.1894, introduced in 1988, actually did propose that EPA establish a 6-12 hour ozone standard.

In its assessment of the extensive 1986 EPA study on ozone, the Office of Air Quality Planning and Standards concluded:

The most directly applicable exposure-response information for a short-term standard is from controlled human exposure and field studies. . . . Of less certain quantitative use for standard setting are the epidemiological and toxicological studies. Epidemiology has associated ambient ozone exposures with lung function decrements, symptoms, and aggravation of existing respiratory disease. Animal toxicology data provide acute and chronic exposure effects, information on increased susceptibility to respiratory infection, lung structure damage, and extrapulmonary effects, but possible differences in human vs. animal dosimetry and species sensitivity produce large uncertainty in the use of these data to assess the risks to human health at ambient levels.<sup>30</sup>

The EPA office recommended that the current National Ambient Air Quality Standard for ozone be retained. It did suggest that the ozone levels of concern should be in the range of 0.08 to 0.12 ppm and that a six- to-eight-hour primary standard should be considered if new data being developed seem to indicate that it is warranted. The report concluded, "Further analysis will be required before fully accessing the need for a separate standard to protect against chronic effects of ozone."<sup>31</sup>

**Conclusion.** In summary, it seems clear that elevated concentrations of ozone produce adverse health effects. These effects are greatly influenced by levels of exercise, thus suggesting that significant numbers of at-risk individuals may be able to reduce the effects of smog by altering their behavior. For example, indoor concentrations of ozone are substantially lower than ambient outdoor levels. Demonstrated effects have largely been short-term (acute) effects of a relatively mild and reversible nature.

On the other hand, there is a clear need for further medical research on possible chronic effects of ozone or effects of exposures of a longer duration.

### **Agricultural Effects**

Ozone pollution has been identified as a potential cause of crop damage. Because of Clean Air Act requirements to promulgate secondary air quality standards for designated pollutants that can adversely affect human welfare, the EPA has authorized a number of studies to assess crop losses from elevated ozone levels. Impacts of ozone range from reduced plant growth and decreased yield to

Table 3.2

**PROJECTED LOSS IN CROP YIELDS DUE TO ELEVATED  
OZONE LEVELS IN RURAL AREAS OF THE UNITED STATES**  
(Ozone concentrations are seasonal average  
seven-hour mean levels)

| Crop     | Percent Yield Reduction<br>at 0.04 ppm ozone <sup>1</sup> | Percent Yield Reduction<br>at 0.06 ppm ozone <sup>2</sup> |
|----------|-----------------------------------------------------------|-----------------------------------------------------------|
| Cotton   | 4.6 to 16.0%                                              | 16.0 to 35.0%                                             |
| Wheat    | 0.0 to 29.0                                               | 0.9 to 51.0                                               |
| Soybeans | 1.7 to 15.0                                               | 5.3 to 24.0                                               |
| Corn     | 0.0 to 1.4                                                | 0.3 to 5.1                                                |

<sup>1</sup> The 0.04 ppm level is exceeded throughout the southern and eastern halves of the United States.

<sup>2</sup> The 0.06 ppm level is exceeded in parts of the northeast, California, Texas and Georgia.

*Source: Urban Ozone and the Clean Air Act: Problems and Proposals for Change* (Washington, D.C.: Office of Technology Assessment, April 1988), p. 41.

changes in crop quality.<sup>32</sup> Effects on growth and yield have been shown for average ozone concentrations above 0.05 ppm lasting at least two weeks.<sup>33</sup>

Table 3.2 shows the range of crop yield reductions predicted for the four major crops most likely to be affected by elevated ozone levels. The table shows the possible effects for exposure to a seasonal average of seven-hour mean ozone concentrations of 0.04 and 0.06 ppm. The reductions are relative to yields for these crops exposed to background (natural) ozone levels of 0.025 to 0.03 ppm. The predictions come from an eight-year study called the National Crop Loss Assessment Network.<sup>34</sup> The table shows a wide variation in yield losses for different hybrids of the same crop -- 1 to 51 per-

cent for wheat at 0.06 ppm of ozone. It also shows very different effects on different crops -- corn seems virtually unaffected whereas wheat and cotton experience significant yield losses.

Most studies of ozone's agricultural effects have used longer exposure times and a greater frequency of higher ozone levels than normally occur in ambient air. This makes application of the results of these experiments somewhat questionable. Another difficulty with estimating agricultural costs of elevated ozone concentrations is that there are very few air pollution monitors in rural areas.

From a public policy perspective, a key issue is how to calculate the value of crop losses in a market characterized by price supports and land set-aside payments. Nonetheless, estimates of the agricultural benefits from reducing ozone levels are provided in a later section of this report. These estimates take into account the "dead weight" social costs imposed by current agricultural policy.

Agricultural crops are not the only vegetation to suffer reduced growth rates and shorter life spans; forests are also affected. As should be expected, the forests of California show the most tell-tale signs of polluted air. The average daytime (14 hour) ozone concentrations in June through August at sites in the San Bernadino National Forest (east of Los Angeles) are typically 0.10 ppm.<sup>35</sup> "Ozone has been suggested as a factor in several confirmed and reported cases of forest and species decline in the United States."<sup>36</sup>

After observing problems occurring in the forests, researchers have duplicated the symptoms in controlled laboratory exposure studies. Consequently, ozone is generally held to be "a principal cause of visible injury and accelerated mortality of ponderosa and Jeffrey pine and other species in the San Bernadino and San Gabriel Mountains of Southern California."<sup>37</sup>

**Summary.** Elevated ozone levels clearly do affect vegetation. The effects on crops are better documented than effects on trees and shrubs. The wide range of yield losses for different hybrids of the same crop obtained in agricultural studies of ozone's effects indicates that other factors may be important as well.

### **Causes of Ozone Pollution**

Ozone's adverse effects on health and human welfare have received widespread scientific attention. Scientists are also studying the causes of ozone formation. But understanding the chemistry of ozone formation is not the same as knowing with certainty how to reduce urban smog.

Ozone, a major component of photochemical smog, is not emitted directly into the air. It is formed through complex chemical reactions between emissions of volatile organic compounds (VOCs)

primarily hydrocarbons, and nitrogen oxides ( $\text{NO}_x$ ) in the presence of sunlight and oxygen. Both hydrocarbons and nitrogen oxides are emitted by transportation and industrial sources. EPA nationwide figures for 1987 show that the major VOC emissions sources were: (1) industrial processes (generating 8.3 million metric tons or 42 percent); (2) transportation (6.0 million metric tons or 31 percent); (3) fuel combustion (2.3 million metric tons or 12 percent); and (4) solid wastes and miscellaneous sources (3.0 million metric tons or 15 percent of emissions).<sup>38</sup>

Photochemical smog is also directly associated with specific meteorological conditions, especially during periods of above-normal temperatures. The same conditions that are favorable to higher temperatures are also favorable to the formation and accumulation of ozone.

Ozone production follows several distinct patterns. Since the formation of ozone at the earth's surface requires sunlight, there is a minimum level around sunrise (near zero in most urban areas), a maximum level in the early afternoon, and minimal levels again in the evening. Ozone accumulation occurs when temperature-induced air inversions trap the compounds that produce smog from one day to the next.

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*Many factors contributing to elevated ozone levels  
are beyond human control.*

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Ozone also follows a seasonal pattern. During the late spring and summer, when sunlight is most intense and stagnant meteorological conditions are present, conditions are ripe for the formation and accumulation of ozone. The spring and summer months are the "ozone season" for most of the United States.

Many factors contributing to elevated ozone levels are beyond human control. Certain areas of the country are more susceptible to ozone formation than others. The three sectors of the United States which are most severely affected are the Northeast, the Gulf Coast area and the West Coast. This results in part from wind speed and direction, local weather conditions, and irregular atmospheric motion.

In addition, VOCs occur naturally due to emissions from trees and plants. Some investigators believe that these naturally occurring sources are the dominant contributors of VOCs that react with  $\text{NO}_x$  to form atmospheric ozone.

Other researchers contend that at least two-thirds of volatile organic compounds results from man-made sources.<sup>39</sup> This still would



mean that up to one-third of the VOCs in ambient air are naturally produced and beyond the scope of Environmental Protection Agency control. Furthermore, areas such as Baton Rouge, Louisiana where vegetation is a major contributor to VOCs may find it more productive to concentrate on reducing  $\text{NO}_x$  emissions than attempting to further reduce man-made VOC emissions.

Ozone can be transported hundreds of miles from its place of origin. For example, researchers have found that VOCs from the Los Angeles basin are transported over the coastal Pacific Ocean, producing elevated ozone levels in San Diego County.<sup>40</sup> Because ozone moves with air masses, ozone levels can be higher in suburban or rural areas than in urban areas.

Moreover, elevated levels of ozone can persist longer in outlying areas because of the absence of nitrogen oxide for chemical "scavenging." As a scavenger,  $\text{NO}_x$  breaks down photochemical smog formation and improves visibility. Under some circumstances, reductions in nitrogen oxide concentrations in the ambient air can reduce its scavenger role and actually increase the formation of photochemical smog. Thus the role of  $\text{NO}_x$  as both a precursor and a scavenger of ozone is one of the factors that makes it so difficult to deal with smog problems.

**Summary.** Predicting, much less controlling, ozone levels is difficult. The combination of weather conditions and natural and man-made emissions of pollutants that form ozone make the objective of decreasing peak ozone levels problematic. Furthermore, a key ingredient of ozone,  $\text{NO}_x$ , also can reduce ozone levels under certain conditions. Thus a regulatory approach that does not take specific local circumstances into account is likely to produce disappointing results.



#### 4. THE COSTS AND BENEFITS OF REDUCING OZONE LEVELS

##### There Are No Panaceas

There are no "silver bullets" that can bring into compliance all of the 83 urban areas that did not meet the 0.12 ppm ozone standard during the 1986-1988 period. (See Table A-3.1.) Several methods required by current law can reduce 1987 VOC emission levels by a total of 18 percent by 2005. By 1995, these measures alone should reduce the out-of-compliance areas to 58; however, without added controls, population growth and increased automobile usage could increase that number to 72 by 2005.<sup>41</sup>

President Bush's clean air proposal identifies ten new measures that could reduce VOCs by an additional 27 to 30 percent. The largest projected reduction would result from reducing summertime fuel volatility to a Reid Vapor Pressure of nine pounds per square inch (psi) -- a February 1989 law calls for a 10.5 psi standard -- resulting in a 10 percent decrease in emissions. Bush's "clean fuels program," which mandates that one million vehicles capable of operating on methanol, natural gas or ethanol be produced in 1997, would reduce nationwide VOC emissions by 2 to 5 percent.

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*Mandating cities to reduce emissions three percent annually  
may be an exercise in wishful thinking.*

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The Administration projects that these added measures would bring all but 20 cities into compliance by 2005. The White House fact sheet outlining the President's proposal did not specify these twenty cities. However, from the data in Table 2.1 we can infer that they are the twenty areas that require the greatest percent net reductions in VOCs. These twenty areas that would continue to be out of compliance have a current population of 36 million.

According to the White House, if these same cities were required to "take steps to cut ozone-causing emissions by 3 percent per year beginning with enactment of the legislation," then all but three of these last 20 cities could be brought into compliance by the year 2000. Whether mandating these reductions actually can cause these cities to find innovative ways to accomplish these results or whether this is just an exercise in wishful thinking remains to be seen.

Furthermore, the VOC reductions projected for the ten new measures proposed by the President are averages; their impact on individual nonattainment areas may be more or less than this figure. As mentioned previously, smog chemistry is complicated, especially

since  $\text{NO}_x$  serves both as a precursor and as a scavenger of ozone. As Table 2.1 indicates, the effectiveness of VOC reductions in decreasing ozone formation is sensitive to the ratio of VOC to  $\text{NO}_x$  emissions. In addition, the composition of emission sources is very different from city to city, depending upon automobile usage, types of industries located in the area, etc. EPA considers these factors in its models. Nevertheless, incorrect information on true emission inventories of VOCs and  $\text{NO}_x$  can play havoc with these sophisticated models. (See Section 5, "Why Has Progress Been So Slow?")

### **The South Coast's Brave New World**

The extreme case of nonattainment is, of course, Los Angeles and its surrounding area -- the South Coast Air Basin. In September 1988, the South Coast Air Quality Management District, in an effort to head off having the EPA write the state's implementation plan, proposed a three-tier, twenty-year plan to achieve attainment. The elements of this plan demonstrate the great difficulty in bringing this area into ozone compliance.

Little information was supplied in the South Coast plan on costs and benefits. The plan's executive summary did project that Tier I measures would cost \$8 million a day (nearly \$3 billion a year) or 65 cents a day for each resident in the Basin. The South Coast Air Quality Management District also projected per capita air quality benefits from Tier I controls of \$2 a day. (Note: This benefit estimate would amount to \$6 - 9 billion a year -- much higher than nationwide benefits for full compliance estimated by other sources and quoted later in this section of the study.) These measures would reduce the area's design value for ozone from 283 percent (0.34 ppm) of the EPA standard to about 170 percent (0.20 ppm) within five years time.<sup>42</sup>

Tier I controls are by no means easy to attain. They include: twenty-two control measures for paints, solvents, aerosol sprays, and underarm deodorants; fifteen added controls on refineries and petroleum distribution systems; ten measures to control smaller sources; nine added restrictions on residential hot water heaters, furnaces, and public wastewater treatment works; tighter controls on agricultural sources and major point sources; stricter tailpipe emissions standards for vehicles and clean fuels for fleet vehicles; twenty-two control measures to reduce vehicle use, improve traffic flow, improve public transit, and manage growth; and thirteen other requirements for aircraft, ships, locomotives, pleasure boats, etc.

Tiers II and III require even more advanced technology. Tier II will require converting 40 percent of passenger vehicles and 20 percent of freight vehicles to operate on clean fuel. Other mobile

source emissions and emissions from solvents, coatings, and consumer products would need to be reduced by 50 percent. Because the methods to accomplish Tier II goals are uncertain, no costs or benefits were provided. It is safe to assume that the benefits will be considerably less than from Tier I measures, because Tier II reduces design values by about 16 percent (to 0.17 ppm from 0.20 ppm) as compared to the 41 percent reduction resulting from Tier I. Tier II goals are expected to be achieved within ten years time.<sup>43</sup>

Tier III measures are not spelled out in the executive summary of the South Coast plan for good reason. The executive summary states, "Achieving the Tier III emission reduction goals depends largely on research and technological breakthroughs that may reasonably be expected to occur during the next two decades."<sup>44</sup> One potential provision mentioned is banning all gasoline-powered vehicles by 2007.

All three phases have features implying significant lifestyle changes -- eventual elimination of free municipal parking, location of housing near job centers to reduce commuting, eliminating fast food drive-through service, banning barbecue starter fluid, etc. Business-oriented groups such as the California Council for Environmental and Economic Balance have lambasted the plan, estimating costs to be \$15 billion a year or about \$2,500 a family. On the other hand, environmental activists such as Mark Abramowitz, program director for the Coalition for Clean Air, say the South Coast plan is not tough enough. "There are loopholes in here large enough to drive a truck through," says Abramowitz. "Much of the plan at this stage is unenforceable, vague and lacking in commitment."<sup>45</sup>

**Summary.** Clearly, there are no simple solutions for the areas with the greatest smog problems. Furthermore, given the relatively mild health effects documented thus far for low ozone levels, it behooves regulators to consider the costs of further reductions in ozone concentrations in relation to the benefits. The following sections examine overall costs and benefits and the cost-effectiveness of several proposed control measures.

### **Overall Benefit Estimates**

The Clean Air Act does not require that decisions relating to control measures utilize cost/benefit or cost-effectiveness analysis. As a result, there is not an abundance of estimates of the costs or benefits of achieving improvements in urban smog. Nonetheless, recent reports do provide some rough but useful estimates of aggregate benefits and costs.

**Health Benefits.** One comprehensive, but preliminary, study of

acute human health and agricultural benefits was conducted by Alan Krupnick and Raymond Kopp, of Resources for the Future for the Office of Technology Assessment.<sup>46</sup>

The study by Krupnick and Kopp provides benefit estimates in connection with various decreases in ambient ozone concentrations. Their study uses a willingness-to-pay method of benefit estimation, and focuses upon reductions in acute health effects. The willingness-to-pay method of benefits estimation asks people how much they would be "willing to pay" to avoid a day (or part of a day) of a health effect or group of effects.

Krupnick and Kopp do not attempt to extrapolate benefits for those health risks not yet clearly documented (such as increased susceptibility to disease), nor do they try to value bundles of symptoms differently than the sum of the individual symptoms.

Only studies asking individuals to directly value decreased health effects are used by Krupnick and Kopp. They then use concentration-response functions to determine the changes in ozone concentration necessary to elicit those decreases in health effects.

Because the reported dollar values for symptom reduction varied widely and resulted in great uncertainties underlying these estimates, the values of symptom reductions were divided into three groups -- "low," "mid," and "high" estimates -- to reflect this variance. Aggregate benefits were separated by their underlying clinical and epidemiological concentration-response functions. In addition, the clinical benefits were calculated for a "high clinical" and "low clinical" case. The "high clinical" case assumes that two two-hour incidences of a symptom are enough to equal a day of symptoms and that the effects of ozone are felt at any exercise rate above rest. The "low clinical" case assumes that eight two-hour incidences are necessary to constitute a day of symptoms and that the effects of ozone are restricted to periods of heavy exercise.

Krupnick and Kopp present seven scenarios and calculate benefits for each of them. The scenarios include rollbacks to different air quality standards (0.10, 0.12, and 0.14 ppm), straight percentage rollbacks (35 percent and 50 percent), and one rollback to 0.12 ppm with a benefit threshold set at 0.06 ppm. A summary of these results is presented in Table 4.1.



Table 4.1

**SUMMARY OF TOTAL HEALTH BENEFITS BY SCENARIO  
AND AGGREGATION PROCEDURES**

| Scenario                                           | Type of Study    | Total Benefits<br>(millions of 1984 \$'s) |       |        |
|----------------------------------------------------|------------------|-------------------------------------------|-------|--------|
|                                                    |                  | Low                                       | Mid   | High   |
| I. 0.12 standard,<br>1983 ozone data               | Epidemiological  | \$143                                     | \$538 | \$1508 |
|                                                    | Clinical -- High | 646                                       | 1791  | 4505   |
|                                                    | Clinical -- Low  | 49                                        | 136   | 343    |
| II. 0.12 standard,<br>1983-85 data                 | Epidemiological  | 148                                       | 552   | 1528   |
|                                                    | Clinical -- High | 667                                       | 1864  | 4730   |
|                                                    | Clinical -- Low  | 51                                        | 142   | 360    |
| III. 0.14 standard,<br>1983-85 data                | Epidemiological  | 105                                       | 393   | 1091   |
|                                                    | Clinical -- High | 475                                       | 1319  | 3321   |
|                                                    | Clinical -- Low  | 36                                        | 100   | 252    |
| IV. 0.10 standard,<br>1983 data                    | Epidemiological  | 213                                       | 789   | 2178   |
|                                                    | Clinical -- High | 954                                       | 2677  | 6842   |
|                                                    | Clinical -- Low  | 73                                        | 204   | 520    |
| V. 35% rollback,<br>1983-85 data                   | Epidemiological  | 54                                        | 192   | 506    |
|                                                    | Clinical -- High | 248                                       | 684   | 1711   |
|                                                    | Clinical -- Low  | 19                                        | 52    | 130    |
| VI. 50% rollback,<br>1983-85 data                  | Epidemiological  | 91                                        | 328   | 874    |
|                                                    | Clinical -- High | 416                                       | 1153  | 2903   |
|                                                    | Clinical -- Low  | 32                                        | 88    | 221    |
| VII. 0.06 threshold,<br>1983 data<br>0.12 standard | Epidemiological  | 123                                       | 461   | 1303   |
|                                                    | Clinical -- High | 566                                       | 1566  | 3919   |
|                                                    | Clinical -- Low  | 43                                        | 119   | 298    |

*Source:* Alan J. Krupnick and Raymond J. Kopp, *The Health and Agricultural Benefits of Reductions in Ambient Ozone in the United States* (Washington, D.C.: Resources for the Future, Discussion Paper QE88-10, August 1988), adapted from Table 6-4, p. 6-3.



The two researchers found that their estimates of health benefits could differ by a factor of one hundred. Depending upon the assumptions, the benefits of reaching the current ozone standard of 0.12 ppm range from \$51 million to \$4.7 billion a year (using 1983-1985 baseline ozone concentrations). Assuming benefits are derived only by heavily-exercising individuals, the benefits of reaching the 0.12 ppm standard range from \$51 million to \$360 million; while if all exercising individuals receive benefits proportional to their exercise level, the benefits range from \$667 million to \$4.7 billion.

Of greatest interest for comparison of benefits and costs are Krupnick and Kopp's analysis of an across-the-board 35 percent reduction in VOCs. The estimates of benefits, assuming the "high clinical" case and a 35 percent reduction (Scenario V) in emissions, range from \$248 million to \$1.7 billion with a midpoint of \$684 million.

These figures can be used to derive a *very rough* estimate of the dollar benefits for each ton of VOCs removed. Revised EPA figures indicate that nonattainment-area VOC emissions in 1985 were approximately 11 million metric tons, thus a 35 percent reduction would amount to 3.8 million tons. Assuming the "high clinical" parameter and adjusting benefits to 1988 dollars, acute health benefits range from \$70 to \$500 a ton.

**Benefits to Crops and Forests.** The effect of elevated ozone concentrations on plants has been the subject of a number of laboratory and field studies in recent years. High concentrations of ozone can result in significant crop losses and forest growth reductions. Plants are working their hardest to grow and store energy from the sun at the same time of day that ozone readings are their highest. No estimates are available for benefits to forests of reducing ozone but a number of studies do project agricultural benefits.

Two separate studies calculated the same approximate level of agricultural benefits -- \$2 billion (in 1985 dollars) -- for ozone concentration reductions of nearly 25 percent in rural areas.<sup>47</sup> OTA estimates the benefits to crops of a 25 percent drop in nationwide ozone concentrations to be between \$.5 and \$1 billion.<sup>48</sup>

Lower agricultural estimates were calculated by Krupnick and Kopp. At a 25 percent rollback of ozone levels, they estimate benefits to major crops (corn, cotton, soybeans, and wheat) to range from \$262 million to \$386 million in 1986 dollars, depending upon the year in question.

Krupnick and Kopp's estimates attempt to account for the deadweight loss imposed by agricultural policies such as price floors and various acreage subsidies. But even when these deadweight losses are not considered, their benefit estimates are lower than other

studies report. Without the policy considerations, agricultural benefits from a 25 percent rollback of ozone levels range from \$424 million to \$480 million.

Higher estimates are computed for a rollback of 50 percent. Taking minor crops into consideration, these estimates of benefits range from less than \$600 million when the deadweight losses from policy are included to a little over \$1 billion when policy is not considered.

**Summary.** The most appropriate figures for health-related benefits are based on willingness of individuals to pay to avoid a variety of ozone-related symptoms. Krupnick and Kopp derive health-related benefits for a variety of scenarios, estimating benefits of reaching ambient ozone levels of 0.12 ppm to range from just over \$50 million to \$4.7 billion a year.<sup>49</sup>

Krupnick and Kopp warn that the benefit estimates for human health and agricultural products are not calculated on a comparable basis and hence are not strictly additive. They estimate health benefits for rollbacks of 35 and 50 percent of VOC emissions but base agricultural benefits on 25 and 50 percent rollbacks of ozone levels, not VOC emissions.

Furthermore, most health benefits occur in urban areas while agricultural benefits accrue to rural areas. If VOCs are primarily reduced in urban areas, few crop benefits may be realized and vice versa.

### **Estimates of Aggregate Costs**

The Clean Air Act does not require consideration of cost-effectiveness or cost/benefit analysis. As a result, aggregate cost projections of meeting the national air quality standard for ozone are derived by adding up piecemeal, generally rough, estimates of costs for the various proposed requirements.

For example, President Bush's ten proposals designed to bring all but 20 cities into compliance by the year 2005 are purported to cost \$3 - 4 billion a year.<sup>50</sup> No breakdown of these costs was provided in the June 12 White House fact sheet. The fact sheet did estimate that these ten new steps would reduce emissions by 27 to 30 percent from 1987 levels.

The most comprehensive estimate of aggregate costs for new methods of reducing ozone levels is contained in a July 1989 Office of Technology Assessment (OTA) paper, "Catching Our Breath." These cost estimates provide ballpark figures to be compared with admittedly crude benefit estimates.

There is considerable, but not complete, overlap between the proposals evaluated by OTA and those in the President's package.

It should be kept in mind, however, that costs are sensitive to the time allowed for change. Nevertheless, OTA does project significantly less benefit from existing measures taking effect in the 1990s. Its report states:

Total manmade VOC emissions . . . will remain about the same for about a decade. Substantially lower emissions from cars and trucks should offset sizable increases from stationary sources . . . .<sup>51</sup>

This projected balancing of VOC reductions and increases contrasts sharply with the President's figure of 18 percent improvement from existing control measures. A 1989 requirement to reduce gasoline volatility in the summer months to 10.5 pounds per square inch explains about 10 percent, and other changes in mobile source models -- effects of greater use of fuel-injected engines -- bring the two estimates closer together.

With these caveats in mind, let us examine the OTA figures. The ten control strategies and their effectiveness are shown in Table 4.2.

OTA projects total reductions of about 34 percent by 1994. The figures in Table 4.2 total about 27 percent with the remaining 7 percent coming from existing controls that reduce 1985 baseline emissions.

The 1989 OTA report states:

Applying all these controls in all nonattainment cities would cost those cities between \$4.2 and \$7.1 billion per year in 1994 and between \$6.6 and \$10 billion annually by 2004.<sup>52</sup>

Aggregate cost figures do not provide sufficient information for making decisions about particular control measures, however. Proposals to reduce ozone levels need to be analyzed on an individual basis. A brief analysis of the cost for each ton of VOCs removed for several specific proposals follows. These individual figures are quite rough and suffer from having to be averaged over the entire nation, whereas the cost-effectiveness of each can vary considerably over geographic areas.

### **Effectiveness of Control Measures**

As mentioned previously, there are no panaceas for reducing urban smog to the levels deemed healthful in the Clean Air Act. Moreover, cost-effectiveness evaluations are not available for many of the control measures being proposed to reduce ozone levels.

Nonetheless, EPA and the Office of Technology Assessment have gathered cost-effectiveness estimates for a variety of control measures that apply on a broad nationwide basis. The following section analyzes the potential emission reductions, the cost per ton, and

Table 4.2

**EFFECTIVENESS OF NEW CONTROL MEASURES  
IDENTIFIED IN THE 1989 OFFICE OF TECHNOLOGY  
ASSESSMENT STUDY**

| Control Strategy                                                                                                                 | Percent<br>VOCs Reduced<br>(from 1985 baseline) |       |
|----------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|-------|
|                                                                                                                                  | 1994                                            | 2004  |
| 1. Limits on gasoline volatility<br>(9.0 psi vapor pressure)                                                                     | 11.8%                                           | 13.3% |
| 2. Controls on hazardous waste treatment<br>facilities                                                                           | 5.7                                             | 7.4   |
| 3. All current "reasonably available control<br>technology" placed on existing stationary<br>sources (>25 tons of annual VOCs)   | 4.0                                             | 4.3   |
| 4. Enhanced inspection and maintenance<br>programs for cars and trucks                                                           | 2.0                                             | 1.5   |
| 5. Stage II gasoline vapor recovery <sup>1</sup>                                                                                 | 1.8                                             | 2.0   |
| 6. "Onboard" technology on motor vehicles to<br>capture gasoline refueling vapors <sup>1</sup>                                   | 0.0                                             | 2.2   |
| 7. Adoption of new "Control Technique<br>Guidelines" for smaller stationary sources --<br>autobody shops, wood coating, bakeries | 0.9                                             | 1.0   |
| 8. Substitution of methanol for gasoline as fuel<br>for centrally-owned highway vehicle fleets                                   | 0.2                                             | 0.1   |
| 9. More stringent tailpipe emissions standards<br>for gasoline-fueled highway vehicles                                           | 0.0                                             | 1.3   |
| 10. Architectural coatings                                                                                                       | 0.4                                             | 0.4   |

<sup>1</sup> Stage II and onboard figures are not additive. The two approaches are basically redundant in the long run.

Source: *Catching Our Breath: Next Steps for Reducing Urban Ozone*, (Washington, D.C.: Office of Technology Assessment, July 1989), Tables 6-6 and 6-8.



the total cost of reducing VOC emissions by: (1) applying reasonably available control technology to point and area sources; (2) requiring an enhanced inspection and maintenance program for vehicles; (3) instituting transportation control measures; (4) reducing fuel volatility; (5) requiring service stations to install Stage II fuel recovery systems; and (6) mandating onboard fuel recovery systems for autos. Figures 4.1-4.3 summarize our findings.

Figure 4.1 illustrates the percentage of 1985 baseline VOC emissions potentially reduced by each of these control strategies in the years 1994, 1999, and 2004, according to our analysis. These figures are nationwide averages for all nonattainment areas; actual reductions almost certainly vary across cities. The reductions in each city depend upon its industrial base, population demographics, current state and city ordinances, etc. Therefore, these numbers should not be used indiscriminately to calculate a specific city's potential VOC reduction.

The reductions in baseline emissions shown in Figure 4.1 are not net emissions, however. Population growth and increased automobile traffic can add to the emissions inventory and thus partially offset benefits derived from added controls. Under current law, annual emissions are expected to decrease until 1995 as older vehicles are replaced by their newer, cleaner-running counterparts and as added stationary source controls become fully operational.

**Reasonably Available Control Technologies.** The category of controls producing the largest reduction in VOC emissions, according to our analysis of EPA and OTA data, is called reasonably available control technologies. This category consists of a variety of control measures, each applicable to a particular source of VOCs (e.g. dry-cleaning, petroleum refining, chemical manufacturing, paper coating, etc.). In all, OTA and EPA supplied information on control technologies for forty specific source categories that together emit a substantial portion of controllable VOCs.

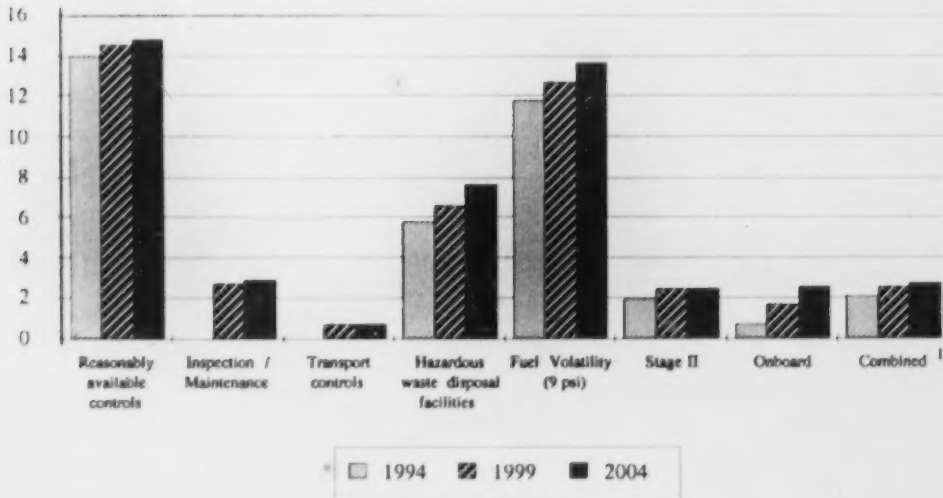
Our analysis indicates VOC emissions can be reduced by 14 percent (from 1985 baseline levels) by 1994 and by nearly 15 percent in 2004 by applying reasonably available control technologies. It should be pointed out that we have aggregated OTA's categories for currently available controls, new control technique guidelines and architectural coatings in our "reasonably available controls" classification.

In phone conversations with EPA personnel, the authors found that the agency does not consider the potential of these added controls to be quite as great as shown in Figure 4.1, however. They indicate that requiring these controls on individual small sources (designated as "area sources" emitting no more than 25 tons of

Figure 4.1

**EMISSION REDUCTIONS POSSIBLE FROM  
NEW CONTROL MEASURES**  
(as a percentage of 1985 baseline emissions)

Percent



<sup>1</sup> Stage II and Onboard are not additive.

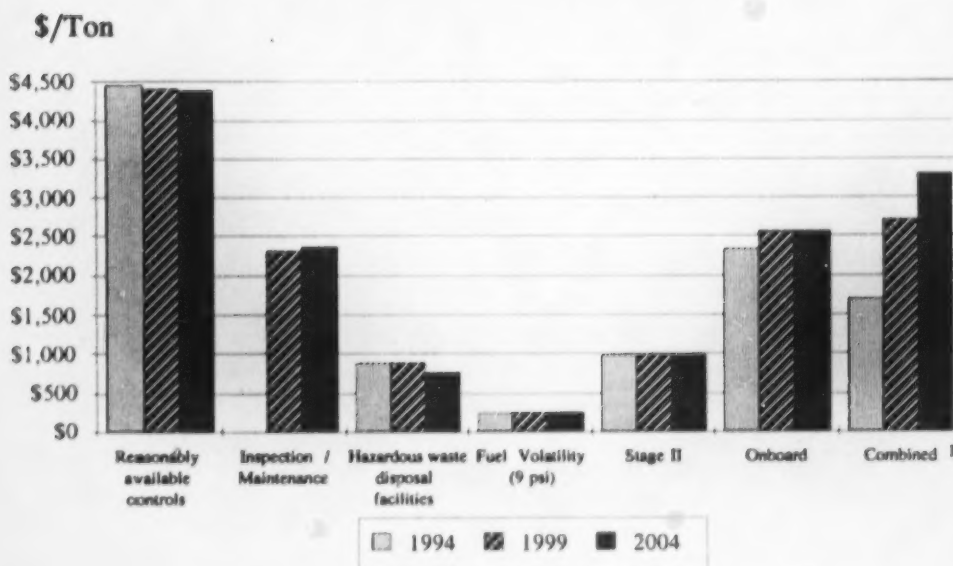
**Source:** Author's calculations for fuel volatility are from Tables 3-21, 3-22, 6-3, 6-4, 6-5, and 6-6 in *Draft Regulatory Impact Analysis: Control of Gasoline Volatility and Evaporative Hydrocarbon Emissions from New Motor Vehicles* (Washington, D.C.: U.S. Environmental Protection Agency, July 1987). Calculations for other control methods from data in *Cost Assessment of Alternative National Ambient Air Quality Standards for Ozone*, Draft Report, October 1987, Alliance Technologies Corporation. Prepared for U.S. EPA Office of Air Quality Planning and Standards.

VOCs a year) would cause many small businesses to shut down.

**Fuel Volatility and Vehicle Emissions Certification.** Another method capable of significantly reducing VOC emissions is to lower fuel volatility. The effects of this control are two-fold. First, lowering fuel volatility significantly reduces "running losses" -- evaporative emissions that occur while a vehicle is in operation. Second, the more volatile the fuel, the less effective the auto emission control

Figure 4.2

# UNIT COST ESTIMATES FOR SELECTED CONTROLS (dollars per ton of VOCs removed)



<sup>1</sup> Stage II and Onboard are not additive.

Source: See source for Figure 4.1.

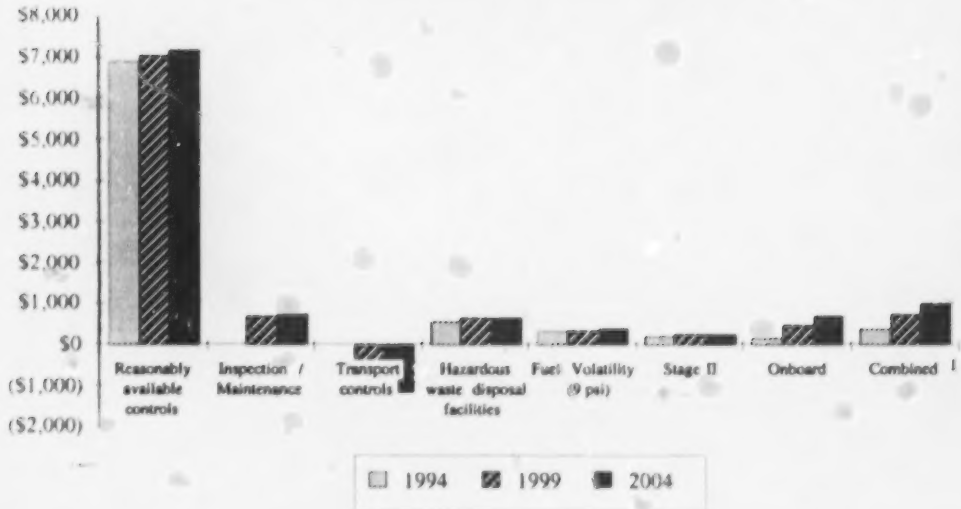
systems, resulting in actual hydrocarbon emissions that are higher than standards dictate. Taking both of these effects into account, lowering in-use fuel volatility to the current level used in testing pollution equipment -- 9.0 psi -- would reduce VOC emissions by 11.5 percent in 1994 and by 13.5 percent in 2004.

Equating the volatility of certification fuels with that of current in-use fuels also could be accomplished by requiring automobile emissions controls to be redesigned to burn higher-volatility fuels. But the preferred strategy appears to be that of lowering in-use fuel volatility to the certification standard of 9.0 pounds per square inch (psi).

When testing procedures and standards were set, most commercial fuels maintained volatilities near this prescribed testing level, but the volatility of fuel has been increasing since the 1970s.<sup>53</sup> The actual average volatility of current commercial gasoline is near 11.5 psi.<sup>54</sup> A February 1989 law now requires a vapor pressure of 10.5 psi, however.

Figure 4.3

**ESTIMATED NATIONWIDE COSTS OF  
SELECTED CONTROL STRATEGIES**  
(costs in millions of dollars a year)



<sup>1</sup> Stage II and Onboard are not additive.

Source: See source for Figure 4.1.

Requiring certification tests that use fuels whose volatility is the same as that expected for commercial in-use fuels shifts the burden of attainment to automakers. This approach yields only modest immediate results because only new cars are affected.

Reducing gasoline volatility to a level consistent with certification fuels places the economic burden on gasoline refiners and produces quicker results. Energy firms indicate, however, that nationwide gasoline volatility cannot be reduced to a vapor pressure of 9.0 psi without substantial capital improvements. This problem might be avoided by initially requiring this level of volatility only in nonattainment and transport areas.

Figure 4.1 assumes equalization of certification fuel volatility with actual in-use fuel vapor pressure at the 9.0 psi level. We also assume the requirement applies only to nonattainment and transport areas.

**Stage II and Onboard.** Vapor recovery systems can be used to control refueling emissions at service stations. There are two differ-



ent technologies available to remove most of these emissions: (1) new cars can be required to adopt "onboard" technology or (2) service stations can be required to install "Stage II" equipment on their pumps. Again, since older cars are not equipped with the onboard device, it will take *at least* ten years for this option to become fully effective. (See Figure 4.1.) Further, because nationwide implementation would be the most economical for onboard controls, *all* the driving public would bear the costs but nonattainment areas would receive disproportionately large benefits.

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*All the driving public would bear the costs of onboard controls but residents in nonattainment areas would receive most of the benefits.*

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Unlike the onboard device, the Stage II equipment does not necessarily have redistributive effects. Stage II is fitted on each gasoline pump, and therefore may be installed in just those areas that are nonattainment or transport areas.

Both strategies for controlling vehicle refueling emissions -- Stage II and onboard -- can attain basically the same VOC reductions in nonattainment areas by the year 2004, about 2.5 percent. But the Stage II control method achieves much larger immediate results. Stage II also provides nearly the same benefits as combining Stage II and onboard controls. Earlier proposals called for the combined strategy but recent bills calling only for Stage II seem to reflect awareness of the costly redundancy of such an approach.

**Other Measures.** Other control methods analyzed in this report are transportation control measures including carpooling and alternative working hours, expanded vehicle inspection and maintenance, and controls on hazardous waste disposal facilities.

#### **Unit Costs of Control Measures**

Figure 4.2 illustrates the average dollar cost per ton of VOC removed (cost-effectiveness) for each of the selected emission control methods. Figures 4.1 and 4.2 present a dilemma: requiring added installation of reasonably available control technologies is quite expensive as a whole (about \$4,500 a ton), but also is capable of reducing the largest percentage of emissions.

Not all "available technologies" can be considered "reasonable" when imposed on small sources. The costs can be prohibitive for fitting some of these "area" sources with the currently available control equipment. For instance, incineration of VOCs at every small surface coating plant is estimated to cost just over \$7,700 a ton. Simi-

larly, controls at small dry cleaners average \$3,600 a ton. These same controls at large dry cleaners (at least 100 tons of VOC emissions a year) cost only \$230 for each ton of VOCs removed.

Unfortunately, the emissions reduced by these very expensive controls make up a major portion of the expected VOC reductions obtainable through applying reasonably available control technologies more widely. If control of these small sources is not assumed, VOC reductions of approximately 8 percent of the 1985 baseline emissions can be achieved by 1999 as a result of applying the remaining technologies. Correspondingly, the cost to eliminate a ton of VOC emissions using reasonably available control technologies is reduced by 40 percent from \$4,400 a ton to \$2,800 a ton.

Size aside, some sources are more expensive to control than others. Specifically, petroleum refining processes cost an average of \$6,900 a ton. Most of this cost arises from controls of crude oil storage tanks. Even though these controls are not very cost-effective, the EPA includes them in their calculations since the costs are not considered so great as to force plant closures.

It is also interesting to note that removing a ton of VOCs using an expanded inspection and maintenance program is about nine times more costly than using fuel volatility controls. In addition, this approach only reduces about one-fifth the emissions as does lowering fuel volatility.

OTA's July 1989 report indicates even greater cost savings possible by eliminating the most costly control alternatives. OTA states:

... if controls costing more than \$5,000 per ton of reductions were excluded from consideration, total annual costs for nonattainment areas would drop to about \$2.7 to \$5.1 billion per year [in 1994], a drop of about 30 to 35 percent. There would be a corresponding loss in reductions of about 2 percent of 1985 emissions.<sup>55</sup>

As with other nationwide averages, these numbers are not necessarily indicative of the cost effectiveness for a specific city. They are pertinent, however, if a particular control is mandated for all nonattainment areas. In this case, flexibility is not allowed, and these nationwide figures are useful for comparing different control strategies.

An important aspect of Figure 4.2 is the ability to compare control alternatives using this information. Stage II controls are more than twice as cost-effective as onboard controls, costing about \$1,000 a ton versus \$2,500 a ton of VOC removed, and from Figure 4.1 we see that onboard controls add little in the way of emissions reduction. Combining these controls is even less cost-effective than choosing Stage II or onboard alone.

Transportation control measures were not incorporated in this graph. Direct dollar *savings* for such measures are estimated to be approximately \$15,000 a ton. (Plotting a number this large collapses the scale of the figure making other data difficult to read.) Moreover, rather substantial inconvenience costs associated with transportation control measures are not included in the cost savings estimate. The July 1989 OTA report cautions, "Involuntary transportation control measures have proven politically infeasible and voluntary ones difficult to sustain."<sup>56</sup>

As Figure 4.1 shows, transportation control measures are not expected to greatly reduce ozone levels nationwide -- less than one percent. There are, however, certain areas of the country where such controls may be more beneficial -- specifically, the South Coast Basin in California.

#### **Aggregate Costs of Control Measures**

Multiplying the average cost of removing a ton of emissions by the number of tons that can be reduced by each control strategy yields an estimate of nationwide costs for each of the individual strategies. Figure 4.3 depicts these costs for the years 1994, 1999, and 2004. The costs shown assume application of the individual strategies wherever necessary. But applying these controls will not achieve the 0.12 ppm standard nationwide.

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*We cannot, by the year 2000, get the entire Nation to the goal that Congress established in 1970.*

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Combining the costs of individual strategies can produce a rough estimate of total nationwide costs for a particular scenario. Such an estimate should include only one vehicle refueling scenario (Stage II, onboard, or combined). Again, inconvenience costs associated with transportation control measures are not included in the savings shown in Figure 4.3. Care should be taken in adding the apparently negative cost of this measure when calculating a total nationwide figure for VOC emissions reductions.

For example, consider a scenario combining reasonably available control technologies with enhanced vehicle inspection and maintenance, hazardous waste disposal controls, equilibrium fuel volatility at a vapor pressure of 9.0 psi, Stage II, and ignoring transportation control savings. The estimated total nationwide cost of this scenario would be approximately \$8.5 billion (in 1986 dollars) and would reduce emissions by 40 percent by the year 2004. Theoretically, this combination would achieve attainment in all but 38 metropolitan

statistical areas by the year 2004.

The July 1989 OTA report sums up the situation as follows:

If we are willing to use and pay for currently available technology, we can make significant advances over the next 5 to 10 years, achieving about two-thirds of the reductions we need. This should bring about half of all current nonattainment areas into compliance. But we cannot, by the year 2000, get the entire Nation to the goal that Congress established in 1970.<sup>57</sup>

### **Temporal Controls**

One group of control measures currently given short shrift is temporal controls -- measures that alter individual and business behavior for critical periods of time. Generally speaking, the fewer the number of hours that an area exceeds the standard, the more effective temporal controls will be. Sixty percent of the worst smog areas would appear to be good candidates for seasonal variations in control requirements -- staggered work hours, reduced commuter traffic, decreased daytime operation of large and small stationary sources of VOC and NO<sub>x</sub> emissions, etc.<sup>58</sup>

The control measures currently prescribed and those proposed are "continuous" control measures. Indeed, the Clean Air Act prohibits including temporal controls in state implementation plans, requiring that all areas attempt to meet the standard using controls that are permanent. As a result the cost savings possible from using temporal controls to reduce ozone levels has not been investigated. One study of continuous versus intermittent abatement techniques for controlling SO<sub>2</sub> in Tennessee found that the cost of meeting the SO<sub>2</sub> standard using temporal measures would be one-fifth the cost of constant controls.<sup>59</sup>

Moreover, health benefits from time-varying controls can be superior in cases where continuous controls are unable to prevent high ozone peaks. While there is much debate about possible threshold levels for ozone effects, it is clear that higher levels have more pronounced incremental effects on larger numbers of individuals. Thus flattening out peak concentrations may produce greater health benefits than continual measures that reduce VOC emissions by a constant amount at all times while not preventing high ozone peaks.

### **Comparisons of Costs and Benefits**

Comparing aggregate costs and benefits of reducing ozone levels is not straightforward. Krupnick and Kopp have estimated the health benefits of reaching the clean air standard for ozone; however, the control measures identified and costed out by EPA are insufficient to bring all areas into compliance. The best that can be



done for aggregate comparisons at present is to compare the costs and benefits of certain percentage levels of VOC reductions. This comparison at least provides some indication of how much benefit is being delivered for taxpayer and consumer dollars spent to reduce smog in America.

Krupnick and Kopp found health benefits from a 35 percent rollback of VOC emissions ranging from \$21 million to \$1.9 billion in 1988 dollars. (See scenario V in Table 4.1.) Agricultural benefits were estimated to range between \$600 million and \$1 billion in 1986 for a 50 percent rollback of ozone levels.<sup>60</sup> Using the most optimistic health benefit estimate, a 35 percent rollback yields \$500 (in 1988 dollars) in benefits for each ton of VOCs removed. (See Table 4.3)

As discussed previously, it is inappropriate to add health benefits to agricultural benefits to obtain a total benefit figure. Since most cost estimates are for controls in nonattainment areas and health benefits are likewise for nonattainment areas, it does seem proper to compare health benefits with compliance costs for reduced VOCs. These comparisons are very rough, however, and should be considered only as "indicators," not precise point estimate calculations.

The June 12, 1989 White House fact sheet on President Bush's clean air plan projected incremental annual costs of \$3 to \$4 billion for reducing VOC emissions from 27 to 30 percent (from a 1987 baseline). No published figures exist for 1987 emissions for nonattainment areas alone, but estimates of this figure from OTA data suggest a cost for each ton of reduction of \$1,200-1,500. Relating benefits to costs for each ton of VOC emissions estimated, shows that costs far outweigh benefits. The ratio of health benefits to abatement costs using White House projections range from 0.3 to 0.4.

The benefit to cost ratios are slightly worse using OTA estimates. OTA projects a 35 percent reduction in VOCs (1985 baseline) at a cost of \$6.6-10 billion. Using the same high estimates of acute health benefits as before -- \$500 a ton -- implies a benefit to cost ratio ranging from 0.2 to 0.3.

Our analysis of EPA data for individual control measures shows nationwide VOC emissions in the year 2004 potentially reduced to 40 percent below 1985 emission levels, excluding a 5 percent reduction attributable to controls already in place by 1988. (Our potential emissions reductions include the effects of reducing average fuel volatility from 1988 levels of 11.5 psi to 9.0 psi, as do the OTA projections.) The White House projects a 30 percent reduction of VOCs over and above the 9.7 percent (of 1987

Table 4.3

**COMPARING ACUTE HEALTH BENEFITS TO COSTS**  
(in 1988 dollars)

|                                           | <u>Health Benefits<sup>1</sup></u> | <u>VOCs Reduced in Nonattainment Areas<sup>2</sup></u> | <u>Average \$Benefit Per Ton</u> |
|-------------------------------------------|------------------------------------|--------------------------------------------------------|----------------------------------|
| Krupnick and Kopp                         | \$1.9 billion                      | 35%<br>(3.8 million metric tons)                       | \$500                            |
|                                           | <u>Abatement Costs</u>             | <u>VOCs Reduced in Nonattainment Areas<sup>2</sup></u> | <u>Average \$Cost/Ton</u>        |
| White House Proposal                      | \$3-4 billion                      | 30% (2.6 mmt)                                          | \$1200-1500                      |
| OTA                                       | \$6.6-10 billion                   | 35% (3.8 mmt)                                          | \$1700-2600                      |
| Center for the Study of American Business | \$9 billion                        | 40% (4.3 mmt)                                          | \$2100                           |
| <u>Benefit to Cost Ratio</u>              |                                    |                                                        |                                  |
|                                           | Krupnick and Kopp/White House      | .33 - .42                                              |                                  |
|                                           | Krupnick and Kopp/OTA              | .19 - .27                                              |                                  |
|                                           | Krupnick and Kopp/CSAB             | .24                                                    |                                  |

## Notes:

- <sup>1</sup> The highest estimate of benefits from a 35 percent rollback of VOCs is \$1.7 billion in 1984 dollars, the high estimate from clinical studies,
- <sup>2</sup> All VOC reductions are for a baseline of 1985 levels -- 11 million metric tons -- except for the White House figures. The White House assumed 1987 baseline levels. A figure of 8.6 million metric tons for 1987 VOC emissions for nonattainment areas was derived by taking nationwide emissions of 19.6 mmt from Table 3.5 of the *National Air Quality and Emissions Trends Report, 1987*, EPA, and multiplying it by 44 percent. The 44 percent factor was derived by dividing nonattainment by total emissions figures contained in Tables 6-1 and 6-4 in *Catching Our Breath: Next Steps for Reducing Urban Ozone* (Washington, D.C.: Office of Technology Assessment, July 1989).

emission levels) to be achieved as a result of the February 1989 law limiting summertime fuel volatility to 10.5 psi.<sup>61</sup> We estimate average nationwide costs for reducing VOCs to be \$2,100 a ton, for a benefit to cost ratio of roughly 0.2.

Keep in mind, however, that this analysis does not include agricultural benefits or any additional costs to reduce rural ozone concentrations. On the other hand, Krupnick and Kopp's upper limit for acute health benefits was used, which may somewhat compensate for excluding agricultural benefits. To be certain, no definitive conclusion should be drawn from such crude estimates, but benefit to cost ratios substantially less than 1.0 raise a warning flag. In general, optimum regulatory levels would occur where marginal benefits and marginal costs are equal -- a point that typically occurs at a level of regulatory stringency less than the point where total benefits and costs are equal. In and of themselves, benefit/cost ratios as low as these indicate that overregulation is occurring -- consumer and taxpayer dollars likely are being misallocated.

### Conclusion

Many of the most polluted areas cannot reach attainment in the foreseeable future, utilizing known control measures. The extremes to which the South Coast Air Quality Management District has gone in its plans to clean up Southern California smog coupled with health benefits for reducing VOCs in nonattainment areas that are a fraction of the abatement costs raises caution flags.

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*More thought needs to be given to opportunity costs --  
health benefits foregone as a result of ineffective spending  
on efforts to reduce ozone levels.*

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The President's proposal hopes to make greater use of economic incentives to improve the cost-effectiveness of control measures. Nonetheless, incremental improvements in environmental quality will typically be more costly than the measures already applied.

The difficulty in meeting the current air quality standard for ozone should cause the EPA, Congress and the Administration to more carefully consider the original Clean Air Act objective of an adequate margin of safety against any adverse health effects. Clearly more information on cost-effectiveness of control measures is needed and more thought needs to be given to opportunity costs -- health benefits foregone in other areas as a result of ineffective spending on efforts to reduce ozone levels.

## 5. WHY HAS PROGRESS BEEN SO SLOW?

According to the latest EPA figures, 88.6 million people were living in areas that exceeded the ozone standard in 1987.<sup>62</sup> This is not to say that no progress has been made in reducing ozone problems, however.

The total number of "exceedance days" -- days where ozone concentrations averaged above 0.12 parts per million for more than one hour -- declined by 38 percent from 1979 to 1987 at the 274 sites monitored by EPA. The second highest daily maximum one-hour concentration at these sites averaged 9 percent less in 1987 than in 1979.<sup>63</sup>

In spite of this progress, however, only 39 percent of the 317 counties that were scheduled in 1979 to reach attainment by December 31, 1982, actually reached this goal by January 1987. Also in 1979, 31 metropolitan areas were given a deadline extension to December 31, 1987, but none of these cities made the standard as of August 1987.<sup>64</sup>

A recent General Accounting Office (GAO) review of the reasons for the lack of progress in meeting the air quality standard for ozone focused on three cities -- Charlotte, North Carolina; Houston, Texas; and Los Angeles, California. The GAO found several key causes:

Some of the planned control measures were not implemented, and some that were implemented were not always being enforced or were not as effective as anticipated. In addition, ozone reductions planned for may not have been realistic because the hydrocarbon emissions inventories were understated . . . . Further, assumptions used in the modeling, and in some cases, incorrect data, as well as the uncertainties that exist in the models may have led to inaccuracies in the ozone plans.<sup>65</sup>

### **Lack of Implementation**

The GAO found that in each of the three areas -- Charlotte, Houston and Los Angeles -- some control measures were not implemented. But lack of implementation of controls on hydrocarbon emissions made a significant difference only in Los Angeles. Some of the details of Los Angeles' failure are instructive.

As of September 1986, 16 of 29 stationary source controls had not been implemented according to the schedule set in the state implementation plan for L.A. The GAO report states, "In general, the measures had not been implemented either because the control technology was not fully developed or the local air quality board considered the measures too costly given the expected reductions."<sup>66</sup>



In other words, merely issuing technology-forcing regulations cannot always accelerate the actual advance of technology. Moreover, although the Clean Air Act does not require cost-benefit analysis, local authorities sometimes make decisions to override state implementation plan provisions based on their own ad hoc analyses.

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*Issuing technology-forcing regulations cannot always  
accelerate the actual advance of technology.*

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Similar problems surfaced in implementation of the mobile source control measures and transportation and energy measures. Mobile source programs called for use of alternative fuels, emission standards for motor boats, and electrification of railroad line haul operations. Only three of 31 transportation and energy measures were completed or on schedule in 1987, and these three accounted for only 7.4 percent of the reductions expected to come from this category.<sup>67</sup> Thus much of Los Angeles' implementation plan was not carried out because local government deemed it technologically or economically infeasible.

#### **Lack of Enforcement and Ineffective Measures**

A 1986 audit by the EPA and the California Air Resources Board shows that emission reductions at 230 industrial facilities and 424 gasoline stations were 10 percent less than anticipated because sources did not have permits or were not complying with those permits. EPA also found that Mecklenburg County (Charlotte, NC) was remiss in its inspections and enforcement. In fact, the county had allowed variances to regulations and compliance extensions without EPA's approval.<sup>68</sup>

The results of vehicle inspection programs were also less than anticipated. In Los Angeles, emissions reductions from the inspection and maintenance program were about half that expected. A prime shortcoming of the plan appears to be that state legislation exempts compliance if repair costs exceed \$50.<sup>69</sup> Political actors seem to be reticent to burden the voting public with cleaning up their own air. Given consumer/voter revolts associated with the auto seatbelt interlock system and the ban of saccharin, elected officials' actions regarding pollution equipment repairs may have judged citizens' desires very accurately.

### **Understated Hydrocarbon Emissions Inventories**

The third major source of slower-than-expected progress cited by the GAO is underestimation of hydrocarbon (VOC) emissions. As the GAO study states, "As part of the planning process, states and local areas take an inventory of how much hydrocarbon is being emitted (current and for the period covered by the plan) and from what sources . . . . If the inventory figure is understated, an area will not identify enough controls to reduce the ozone."<sup>70</sup>

Several sources of emissions were omitted or understated in the state implementation plans for the three cities studied by the GAO. None of the areas included hydrocarbons emitted by hazardous waste treatment, storage and disposal facilities although EPA estimates that this source may contribute from 3 to 10 percent of total VOC emissions.<sup>71</sup> Both Charlotte and Los Angeles underestimated vehicle mileage growth. L.A. projected a 14 percent growth in annual vehicle miles traveled during the 1979 to 1985 period but experienced 26 percent growth. Charlotte's planners underestimated their vehicle emissions by about 20 percent because they used state transportation department data that did not include all of Mecklenburg County.<sup>72</sup>

Other factors leading to underestimates of emissions inventories include: (1) stationary sources operating without permits or exceeding permissible levels, (2) deterioration of automobile engine performance, (3) auto emission control system tampering (a 1985 survey in Charlotte found 19 percent of inspected vehicles had at least one emission component disabled or removed), and (4) higher-than-expected fuel volatility. For the most part, these factors are not caused by conscious underestimates on the part of state and local planners but from a variety of uncertainties concerning growth patterns and a lack of accurate information on specific sources of emissions.

### **Modeling Uncertainties**

EPA and the states use separate computer models for mobile and stationary sources. As might be expected, differing assumptions and methods embedded in these models can, in and of themselves, produce different results. Modeling is by no means an exact science. Furthermore, models are continually being revised to produce better results.

For example, older mobile models assumed fuel volatility of 9.0 pounds per square inch Reid Vapor Pressure and no tampering with auto pollution equipment. Gasoline volatility was 11.5 psi in 1985 but will be required to be at or below 10.5 psi for the summer

months as the result of a 1989 law. EPA estimates that daytime evaporative emissions from autos more than double when volatility is at 10.5 psi instead of the presumed 9.0 psi.<sup>73</sup> Newer models presume 10.5 psi fuel volatility.

Stationary source models have undergone a similar evolutionary process. Three basic models have been the most popular: (1) the urban airshed model, (2) the empirical kinetic modeling approach and (3) the linear rollback modeling method. The linear rollback model which assumes that ambient levels of ozone are directly proportional to VOC emissions is no longer accepted by EPA. But this technique was used by Charlotte in its 1979 plan and helps to explain why the area did not reach attainment by December 31, 1987.

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*Even the best ozone models can produce results  
that vary by plus or minus 30 percent.*

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EPA generally prefers the urban airshed model to the empirical kinetic approach. The urban airshed model is believed to do a better job of estimating attainment, even though it has a tendency to underestimate peak ozone levels. But even this favored modeling approach has been shown to produce results that vary by plus or minus 30 percent.<sup>74</sup>

Another key factor affecting stationary source model accuracy is the ratio of hydrocarbon to nitrogen oxide emissions. As mentioned in the section of this study discussing causes of smog, the ratio of non-methane volatile organic compounds (NMOC) to  $\text{NO}_x$  emissions can have a significant effect on the percent reduction of hydrocarbons needed to reach the air quality standard. Houston's plan assumed a 5.8 to 1 ratio, which implied that a 41 percent reduction in hydrocarbon emissions was needed. Data collected for Houston in 1985 showed the ratio of non-methane organic compound to nitrogen oxide emissions to be 12.9 to 1 thus necessitating a 71 percent reduction to reach attainment.<sup>75</sup>

Nor are these improved models necessarily the last word in smog modeling. Professor Gregory J. McRae of Carnegie-Mellon University has a 500,000 equation model that projects ozone levels and concentrations of 50 other pollutants for the Los Angeles area. His simulation of Los Angeles pollution took 120 hours on a Cray supercomputer (it would have taken two years on a minicomputer). It showed that Los Angeles would need to control hydrocarbons and nitrogen oxides in combination. Other modelers dispute these results and recommend focusing on hydrocarbons alone.<sup>76</sup>

### **Uncooperative Meteorology**

Another factor slowing progress in reducing ozone goes unmentioned in the GAO study. In the long run, meteorological conditions should not be a factor in determining progress, tending to average out as some years are worse and some better than "normal."

In the short run, however, meteorological conditions are extremely important. Figures for the number of exceedance days or the second highest daily maximum one-hour concentration can vary significantly from year to year with little or no change in emissions. For example, Figure 5.1 shows that EPA's projected composite average of the second highest daily maximum one-hour ozone concentration for 1988 may be the worst since 1978.

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*If the revised Clean Air Act does not take aberrant meteorological conditions into account, totally unnecessary ratcheting of controls and escalation of costs will result.*

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As EPA's National Air Quality and Emissions Trends Report for 1987 states, "The summer of 1988, with its very hot, dry weather and stagnant conditions, was highly conducive to peak ozone levels."<sup>77</sup> Indeed, 1988 was the third hottest summer since 1931 according to the report.

More importantly, the 1988 weather conditions spawned a large number of days where the 0.12 ppm standard was exceeded for more than one hour. Under current and proposed law, an area is out of compliance if it has more than three exceedances in a three-year period. Many urban areas had more than 10 exceedances in 1988 alone. This means these cities will be "nonattainment" areas for ozone for at least another three years even if they have no exceedances in 1989-1990. Additionally, the design values (the fourth highest maximum daily one-hour level) for these areas for the next three years will also be much higher as a result of a single year of adverse weather conditions.

In turn, stricter federal requirements may be placed on these cities for failure to meet ambient air quality milestones. If the revised Clean Air Act does not take aberrant meteorological conditions into account, and at present no proposals do, a totally unnecessary ratcheting of controls and escalation of costs will result.

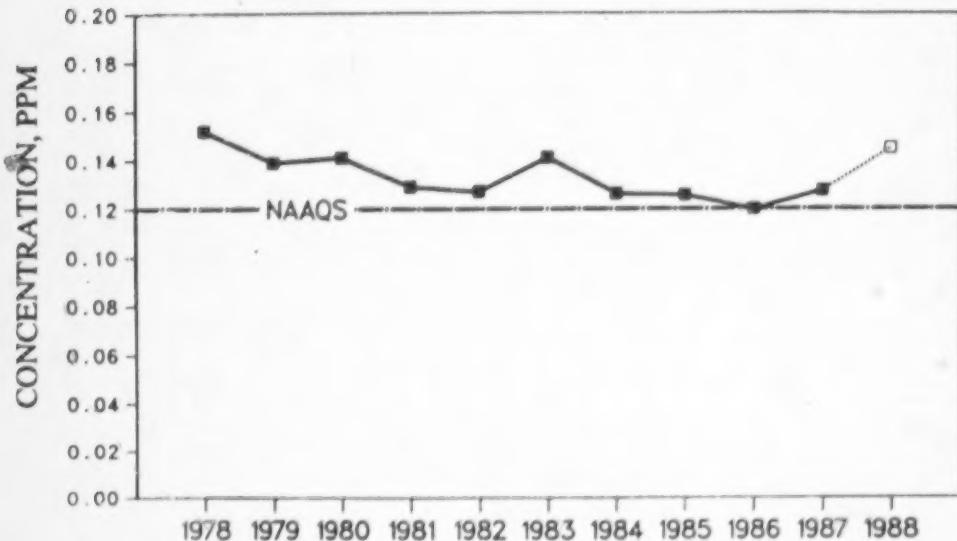
### **Summary**

A variety of factors have conspired to make progress against smog painfully slow during the past decade. In some instances, state and local authorities have been reluctant to implement control mea-



Figure 5.1

NATIONAL TRENDS IN OZONE LEVELS, 1978-1988



Note: 1978 data reflect the use of a different calibration method for measuring ozone concentrations. The 1988 figure is a preliminary estimate.

Source: *National Air Quality and Emissions Trends Report, 1987* (Washington, D.C.: U.S. Environmental Protection Agency, March 1989), p. 79.

tures that they consider to be too costly in comparison to the improvement to be obtained. Enforcement of permitting procedures has at times been lax, and the effectiveness of several control methods was overestimated. Data on hydrocarbon and nitrogen oxide emissions often underestimate the true levels of release. Models of ozone formation are anything but exact and are themselves undergoing revision as is the data being supplied to the models.

Lastly, weather conditions can play a major role in the severity of smog conditions. The best models and most sophisticated controls cannot assure progress when meteorological conditions are highly favorable to ozone formation.

A key issue, as yet not addressed by the drafters of Clean Air Act legislation, is how to measure progress independent of aberrant weather conditions. Currently, Congress and the President seem so intent on mapping out a system of controls and deadlines to achieve ozone reductions that they have not allowed for this important factor.

## 6. LEGISLATIVE PROPOSALS

Various proposals have been offered in 1989 to revise the Clean Air Act. Technically the Act should have been revised in 1981, but competing geographic interests have up until now produced a political stalemate. Acid rain provisions have been the biggest bone of contention — pitting high-sulfur coal states against low-sulfur coal states and New England.

In the recent past, a host of piecemeal bills to deal separately with acid rain, toxic air releases, and ozone was debated. In 1989, there appears to be a good chance of passage of an omnibus bill to truly amend the Clean Air Act.

In a 1988 report, *Clearing the Air: Regulating Ozone in the Public Interest*, the Center for the Study of American Business analyzed the leading Senate bill dealing with ozone, S. 1894, drafted by the Senate Environment and Public Works Committee. Currently, the House of Representatives and the President are taking the lead in Clean Air Act reform.

H.R. 99, the bill proposed on January 3, 1989 by the so-called "Group of Nine" (nine moderate democrats on the House Energy and Commerce Committee) deals with ozone and carbon monoxide nonattainment. Congressman Henry Waxman, Chairman of the Health and Environment Subcommittee, has proposed H.R. 2323 to address ozone, carbon monoxide and particulates. The President's proposal is the only omnibus approach being given a great deal of attention at present. It addresses ozone, carbon monoxide, particulates, toxic air pollutants and acid rain. For the purposes of this report, only the provisions of these three alternatives that deal with ozone will be analyzed.

Table A-2.1 in the Appendix is a compilation of the major features of H.R. 2323, H.R. 99 and the White House proposal. All three proposals recognize that the most severe smog problems cannot be resolved in the near term. Each establishes differing categories or classes for nonattainment areas and specifies deadlines and required remedies for each. Since Table A-2.1 provides much of the detail, the following discussion highlights differences in the proposals.

### **Nonattainment Classification and Deadlines**

The three proposals use differing cutoffs for classes of nonattainment but the differences are not great. The Waxman bill refers to Moderate, Serious, Severe and Extreme nonattainment areas defining these as less than 20 percent above standard, 20 to 50 percent, 50 to 100 percent, and more than 100 percent over standard,

respectively. This bill requires attainment for Moderate, Serious, Severe and Extreme areas within 4, 8, 12 and 16 years respectively.

The Group of Nine's bill also designates four categories, but labels them as Moderate Class I, Moderate Class II, Serious and Severe. (The nomenclature differences are somewhat indicative of the softer more conciliatory approach taken compared to the Waxman bill.) These classes are defined as follows: Moderate Class I (less than 15 percent above standard), Moderate Class II (15 to 25 percent over), Serious (25 to 50 percent) and Severe (more than 50 percent above standard). The bill allows Class I areas 3 years after enactment to be in compliance; and Class II, Serious and Severe areas are allowed 3, 5, and 13 years after SIP approval but no later than 12/31/95, 12/31/99, and 12/31/2005, respectively.

The Bush proposal categorizes nonattainment areas into four different classes as well. Marginal areas are those with design values (the fourth highest one-hour level of ozone in a three-year period) of 0.13 parts per million. The Moderate class is from 0.14-0.15 ppm design value; Serious covers 0.16-0.18 ppm and any area with a design value of 0.19 ppm or above is designated as Severe. The Bush proposal also allows the EPA Administrator to adjust an area's classification if its design value is within 5 percent of the classification cutoff. Marginal and Moderate areas must reach attainment by December 31, 1995, Serious by December 31, 2000, and Severe by no later than December 31, 2010.

By focusing on actual design values for classifying areas and then allowing 5 percent leeway at the Administrator's discretion, the President's proposal creates a small amount of technical confusion. The other proposals define classes based on the percent that the design value falls above standard and create sharp distinctions.

Table 6.1 illustrates the problem. An area with a design value between 0.15 and 0.16 ppm would be "serious" by Waxman standards, "serious" by the Group of Nine definition, but either moderate or serious by the Bush scheme. The discretion given EPA can resolve this minor difficulty but the fact remains that the Bush classifications are confusing.

### **Control Measures**

All three proposals require added federal control measures for each category of nonattainment. But the President's proposal focuses more directly on results than means. Those areas considered to have "moderate" ozone problems, or worse, are essentially required to reduce emissions of VOCs by 3 percent a year, on average.

Table 6.1

**NONATTAINMENT CLASSES IN THE LEADING  
LEGISLATIVE PROPOSALS (PERCENT THAT  
DESIGN VALUE IS ABOVE STANDARD)**

|    | Waxman                                                                                                    | Group of Nine                                                                                                       | President Bush                                                              |
|----|-----------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| 1. | Moderate --<br>20 percent<br>or less ( $\leq 0.144$ ppm)                                                  | Moderate Class I --<br>15 percent or less<br>( $\leq 0.138$ ppm)                                                    | Marginal --<br>8.3 percent or<br>less ( $\leq 0.13$ ppm)                    |
| 2. | Serious -- more than<br>20 percent<br>but not more<br>than 50 percent<br>( $> 0.144$ but $\leq 0.18$ ppm) | Moderate Class II --<br>more than 15 percent<br>but not more than<br>25 percent<br>( $> 0.138$ but $\leq 0.15$ ppm) | Moderate --<br>16.7 - 25 percent<br>(0.14-0.15 ppm)                         |
| 3. | Severe -- more than<br>50 percent but not<br>more than 100 percent<br>( $> 0.18$ but $\leq 0.24$ ppm)     | Serious -- more than<br>25 percent but not<br>more than 50 percent<br>( $> 0.15$ but $\leq 0.18$ ppm)               | Serious --<br>33.3 - 50 percent<br>(0.16-0.18 ppm)                          |
| 4. | Extreme --<br>greater than<br>100 percent<br>( $> 0.24$ ppm)                                              | Severe --<br>greater than<br>50 percent<br>( $> 0.18$ ppm)                                                          | Severe -- greater<br>than or equal to<br>58.3 percent<br>( $\geq 0.19$ ppm) |

There are numerous differences in the proposals -- more than can be discussed in this brief overview. Two major types of controls illustrate the different tone of these three documents.

**Offsets.** The offset mechanism is one of the control procedures consistently tightened in the Waxman and Group of Nine proposals as the nonattainment classification worsens. For areas with moderate ozone difficulties, major stationary sources of VOC emissions (25 tons a year in Waxman's bill and 50 tons for the Group of Nine proposal) must find other sources of emissions that can be reduced by 120 percent of the emissions generated by the new source -- an offset ratio of 1.2 to 1. In the Group of Nine's bill the offset ratio



climbs to 1.5:1 for sources over 100 tons per year of VOCs (staying at 1.2:1 for 50-100 tons) in Moderate Class II areas (15-25 percent above standard). Waxman requires a 1.3:1 offset for emission sources above 25 tons a year in areas 20 to 50 percent above standard. Offset requirements in the Waxman bill climb to 1.5:1 for Severe and Extreme areas (more than 50 percent above standard). The Group of Nine proposal is essentially identical at this point, requiring a 1.5:1 offset for all sources with more than 25 tons of VOC or NO<sub>x</sub> emissions a year.

Both bills further crack down on stationary sources if an area fails to implement its planned control measures or fails to achieve attainment. Waxman requires a 3:1 offset. The Group of Nine proposal prohibits construction or modification of sources emitting more than 50 tons of VOCs or NO<sub>x</sub> a year if an area fails to implement planned controls. In addition, it requires a 2:1 offset from sources emitting over 25 tons a year for failure to achieve attainment. In all likelihood, offsets of 3:1 or even 2:1 are in effect a construction ban. The cost of obtaining such a large offset would likely make new projects economically infeasible.

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*Escalating offsets may forestall an area's economic growth without specifically legislating a no-growth policy.*

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In general, requiring higher offsets for poorer air quality conditions seems "fair." But, in reality, the concept may be more of a punishment system than one designed to improve air quality. In most instances, major sources within areas having poorer air quality have already been required to install costly abatement equipment. As offset ratios climb, it becomes even more expensive to find sources of economical trades. This means that slightly better air quality can be achieved at very high cost, or more likely, air quality does not improve and plants are not built or expanded -- exacting a different type of cost on the local economy.

Indeed, the point of ratcheting offset requirements may be to forestall economic growth without explicitly legislating this result. This form of public policy perhaps unwittingly protects existing firms and industries at the expense of potential entrants.

The Bush proposal does not include any new offset requirements. Instead, EPA is "given the authority to set the rules for determining the amount of offsets necessary" in situations where offsets are required in order to obtain a new source permit.

In general, the tone of the Bush proposal is much more conciliatory, requiring EPA to determine if states are making

"reasonable efforts" to cure any specific planning failures and whether states are making "reasonable further progress." If states are not making reasonable efforts, then the Administrator is authorized (sometimes required) to apply one or more sanctions from a list of three. The three sanctions are similar to current sanctions and to those in the other two proposals: (1) a ban on construction or modification of major stationary sources, (2) a ban on drinking water hookups, and (3) withholding air pollution grants.

**Mobile Source Provisions.** Several requirements in these bills affect the driving public. These measures include: tighter tailpipe emissions, alternative fuel requirements, enhanced inspection and maintenance programs, transportation control measures, reduced fuel volatility, and refueling vapor recovery systems (Stage II) at service stations. Most of these controls were discussed earlier. At any rate, Table A-2.1 highlights the distinction among the approaches.

Nonetheless, let us briefly discuss major differences in the bills dealing with alternative fuel requirements and tailpipe emissions. The Group of Nine bill does not impose a requirement on the general public to phase in alternatively fueled passenger cars. In areas with design values more than 25 percent above the 0.12 ppm standard (38 cities in Table A-3.1 have design values at 0.15 ppm or above), all fleets of at least 15 vehicles and bus fleets of 10 or more, having reasonable access to alternative fuels -- methanol, ethanol or natural gas -- would be required to phase in vehicles using alternative fuels.

Alternative fuel provisions of the Waxman bill directly affect the driving population in areas that are 50 percent or more above standard. This is a much smaller set of cities (11, in total, according to Table A-3.1) but a much more extensive intrusion on individual communities. At least 30 percent of new vehicles registered or operating in a "severe" area (50 to 100 percent above standard) must be low emission vehicles by 1998. In "extreme" areas, the percentage of newly registered vehicles that must be low emission follows a schedule -- 10 percent in 1994, 30 percent by 1996, 70 percent in 1998 and 100 percent by the year 2000.

President Bush's plan takes a different approach, mandating the number of alternative fuel vehicles that automakers must produce and market in the dirty air cities. This approach, referred to as the "clean fuels program," requires clean-fueled vehicle sales of one-half million in 1995, three-quarters of a million in 1996 and one million a year from 1997 through 2004. These vehicles are to be sold in major urban areas with ozone concentrations (design values) above 0.18 ppm.

The mechanism for requiring just a portion of new car buyers to purchase these vehicles, however, is unclear as is the mechanism for assuring supplies of alternative fuels in these areas. The analysis of proposed legislation released by the White House on July 20, 1989 finessed this issue. States are required to include in their implementation plans for clean fuels "all measures necessary to make use of clean alternative fuels in clean fuel vehicles economic from the owner's standpoint." States can opt out of the clean fuels program if they can find other new measures to reduce emissions that are just as effective.

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*A 40 percent reduction in automobile tailpipe emissions would reduce overall VOC emissions by only 0.4 percent.*

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The three proposals also differ greatly with regard to their requirements for reducing tailpipe emissions. The President's approach calls for hydrocarbon emissions to be reduced from 0.41 grams per mile (gpm) to 0.25 gpm, with the phase-in beginning in model year 1993 and completed by 1995. The proposal also allows for "fleet averaging" to reach this goal. Interestingly enough, this 40 percent reduction in auto emissions is projected to reduce overall VOC emissions by only 0.4 percent. The Administration's proposal also requires that light-duty trucks weighing no more than 3,750 lbs. meet the current 0.41 gpm standard for autos by 1995, resulting in 0.2 percent fewer VOC pollutants. Light-duty trucks weighing more than 3,750 lbs. must reduce hydrocarbons to 0.50 gpm by 1994.

The Group of Nine bill would phase in tighter standards for autos and light duty trucks. From 1993 to 1995, the portion of new autos required to meet a 0.25 gpm standard and light duty trucks to meet a 0.5 gpm standard would grow by 30 percent per year until all new vehicles would meet this test in 1996.

The Waxman bill is the toughest of the three. It would require autos and light duty trucks to meet a 0.25 gpm hydrocarbon emissions standard by 1993 and cut that figure in half after 2000. Trucks in the 3,750-10,000 pound range would have to meet a 0.5 gpm standard after 1993.

Given the small percentage improvement in VOC emissions projected by the White House, it is difficult to envision the Waxman tailpipe standards as being cost-effective. Congressman Waxman seems to believe that Detroit is foot-dragging and can do more to reduce its contribution to smog problems if technology-forcing legislation is passed. This type of approach is reminiscent of 1970s-style regulation and consistent with the implicit "progress at any

cost" language of the current Clean Air Act. Judging by past experience, taxpayer and consumer resources will likely be wasted as a result of this overregulation.

### **Summary**

Currently, the three leading Clean Air Act proposals addressing smog problems are H.R. 99 (the Group of Nine bill), H.R. 2323 (Congressman Waxman's bill) and the President's omnibus reform proposal. All three offer a sliding set of deadlines depending upon the severity of existing air pollution. They differ in the criteria for the classes of nonattainment, the deadlines for reaching attainment, and penalties for failing to do so.

All three proposals specify added control measures for each successive class of nonattainment, assuring a key federal role in plans to reduce smog. Offset provisions become more stringent in the Waxman and Group of Nine proposals as pollution categories worsen. Such a ratcheting effect has the appearance of prudence; however, it may mean that old industries and current technology are favored over newcomers, doing little or nothing to reduce emissions.

Mobile source emissions requirements and mandates for new low emissions vehicles are different for all three proposals. None is clear on how consumers will be induced to pay higher prices for alternative-fuel vehicles and for the alternative fuels, themselves. The House bills target fleet vehicles first. Waxman's bill further requires that an increasing percentage of newly registered vehicles be low emission over time, primarily for extreme nonattainment areas. The President's proposed legislation targets the auto industry and requires that an increasing number of alternative-fuel vehicles be marketed in the nine worst areas for ozone pollution from 1995 to 1997 -- the so-called "clean fuels program."

Proposed tailpipe emissions standards also vary. President Bush and the Group of Nine push for a 40 percent reduction in hydrocarbon emissions -- from 0.41 grams per mile to 0.25 gpm -- the level required for the "California car." Waxman calls for a technology-forcing requirement to halve emissions from the proposed 0.25 gpm standard by the year 2000.

For the most part, the three proposals represent improvements over the current Clean Air Act ozone provisions. There is some recognition that all cleanup problems are not created equal -- variable deadlines and control measures are needed. The President's proposal has gained the most attention for its emphasis on economic incentives and market mechanisms. But the Group of Nine proposal also allows a good deal of flexibility, delegating more authority to the EPA Administrator rather than creating a legislative



straitjacket.

Overall, all three proposals still rely on Washington-orchestrated solutions. Other than transport regions that, in essence, inflict their smog on downwind neighbors, ozone is a local and state problem that is best addressed at that level. The fewer federal requirements the better if local residents are going to obtain a desired level of air quality at a cost -- economic and lifestyle -- they believe is reasonable.

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*The fewer federal requirements the better if local residents are to obtain a desired level of air quality at a cost -- economic and lifestyle -- they believe is reasonable.*

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Finally, none of the bills require cost/benefit or cost-effectiveness analysis of proposed controls, although the Bush proposal moves in this direction. Smog is undesirable. But, given the relatively mild health effects of ozone levels commonly experienced, measures to reduce ozone should be determined by taking costs as well as benefits into consideration.

## 7. CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

Clean Air Act provisions dealing with atmospheric ozone are important for two key reasons: (1) they attempt to address a clearly documented public health concern resulting from air pollution, and (2) they demonstrate the practical limits of federally legislated solutions to environmental health risks. Moreover, public and private expenditures to reduce -- but not eliminate -- ozone problems are estimated to total \$100 - 150 billion from 1988 through 2000.<sup>78</sup>

**Slow Going.** In Section 5 of this report, we summarize the findings of the General Accounting Office (GAO) review of three major cities' efforts to reduce ozone levels. The GAO cited three primary factors leading to less-than-planned-for results: (1) lack of enforcement and ineffective control measures, (2) understated emissions inventories, and (3) pollution modeling uncertainties.

We added a fourth reason -- uncooperative meteorology. Unusual weather patterns are a significant issue because the way in which the Clean Air Act defines compliance is quite susceptible to aberrant weather conditions.

But the key issue from a policy perspective is lack of enforcement and ineffective controls. In particular, the reluctance of state and local authorities to implement controls not considered to be cost-effective shows that economic impacts cannot be ignored by Congress. Practical decision makers weigh employment effects and other costs against potential benefits when considering whether or not to implement proposed control measures.

**Ozone's Health Effects.** The adverse health effects produced by elevated concentrations of ozone are well documented. The significance of these effects and the levels of ozone that should be of concern in order to protect public health are debatable, however.

In 1986, the EPA produced a vast compendium of health studies -- clinical and epidemiological. One of the conclusions of this report was that "at the lower concentrations (0.12 to 0.15 ppm), the average changes in lung functions are generally small (less than 5 percent) and are a matter of controversy in regard to their medical significance."<sup>79</sup> Human health studies show the short-term effects of these ozone levels to be relatively mild and reversible. Staying indoors, running air conditioners and avoiding exercise during peak ozone periods -- hot summer afternoons -- greatly reduces the likelihood of respiratory problems. On the other hand, a subgroup of the population, from 5 to 20 percent, seem particularly sensitive to elevated concentrations of ozone.

Some animal studies show a reduction in the lung's ability to resist bacterial and viral infections and an acceleration of the lung's aging process, thus raising some long-term health concerns about ozone. But the significance of these studies for humans is the subject of much debate among medical researchers.

**Benefits and Costs.** The medical evidence presently available would lead most unbiased observers to ask a logical question, "What does it cost to reduce ozone to levels where most people will not suffer significant health effects?" The current Clean Air Act calls for an adequate margin of safety against *any* adverse health effects, without consideration of cost or technological feasibility. Thus EPA is never required to calculate the costs of the current policy versus the cost of avoiding significant adverse health effects. The agency also is frustrated by its inability to carry out this form of "mission impossible."

The best estimates of the costs and health benefits of reducing VOC emissions in nonattainment areas indicate a ratio of health benefits to abatement costs ranging from 0.2 to 0.4 for a 30-40 percent reduction. This does not include, however, the benefits from reduced crop damage. Although there are estimates of nationwide benefits to crops from reduced ozone levels, these figures are not compatible with the health benefit estimates. But when costs exceed benefits, that is a warning signal that the resources of the nation are being used inefficiently.

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*Comparing costs and benefits raises questions about indiscriminately applying all possible control measures to reduce ozone levels.*

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The cost-effectiveness of individual control measures varies widely. Reducing fuel volatility to 9.0 psi appears to be the most cost-effective approach, lowering VOC emissions by more than 13 percent by 2004 at a cost of \$120 to \$750 per ton.<sup>80</sup> Expanding reasonably available control technology requirements for a host of point and area sources potentially produces the greatest reductions in VOCs -- roughly 15 percent by 2004. But these controls are also quite costly -- an average of \$4,400 for each ton of VOCs removed. Theoretically, transportation control measures could actually save money but their nationwide impact on emissions is quite modest -- less than one percent. On the other hand, estimates of health benefits from reducing VOCs range from \$70 to \$500 a ton (in 1988 dollars).

While there is substantial uncertainty about both cost and benefit estimates, comparing the two raises questions about the advisability of indiscriminately applying all possible control measures to reduce ozone levels. Without cost-effectiveness or benefit/cost analysis of individual control procedures, these decisions will continue to be made at the local level in an ad hoc fashion through lack of enforcement and implementation.

**Legislative Proposals.** The primary lesson that Congress and the Administration appear to have learned is that all urban smog problems are not created equal. As a result, all current Clean Air Act proposals allow areas with the most severe ozone problems longer periods of time to reach the clean air standard of 0.12 parts per million. This is an encouraging development.

Nonetheless, the lesson has been learned only partially. By requiring specific additional control measures for each class of nonattainment, the Clean Air Act proposals minimize the uniqueness of urban ozone situations. Ozone formation and concentration is sensitive to such factors as the types of VOCs and  $\text{NO}_x$  emissions, background (natural) sources emitting VOCs and the mix of sources of VOCs and  $\text{NO}_x$ . Mobile sources may be a much more significant contributor to smog problems, say, in Los Angeles than in Baton Rouge. Tailpipe emissions, transportation control measures, fuel volatility, refueling emissions may, therefore, require greater control in Los Angeles. Sources of  $\text{NO}_x$  emissions may be of more concern to Baton Rouge because of significant naturally occurring hydrocarbon releases from vegetation and a high VOC/ $\text{NO}_x$  ratio.

President Bush's nod to the use of economic incentives -- emissions trading -- is also encouraging although the savings possible may not be great when compared with the costs of the mandated portions of the President's proposal. The Group of Nine bill, H.R. 99, gives less attention to market approaches for dealing with atmospheric ozone but, like the Bush proposal, affords greater flexibility, delegating significant authority to the EPA Administrator to determine cost-effective control procedures.

### **Recommendations**

This analysis of urban smog problems leads to a number of recommendations for improving the Clean Air Act. Many of these proposals would affect more than just the ozone provisions of the Act and would improve the cost-effectiveness of all federal air pollution programs. We have avoided specific suggestions in favor of broad guidelines for reform in keeping with our own view that detailed requirements stifle creativity.



*Change the definition of nonattainment to be more consistent with the nature of the public health risk posed by ozone.*

Rather than using the highest ozone reading recorded at a single monitor, an average should be taken of a representative set of monitors in a given area. Furthermore, nonattainment "classes" should be based on the average annual exceedances (the number of times that the average of all monitor readings in the area exceed 0.12 parts per million for more than one hour in a day), as well as, some measure of peak ozone concentration.

For example, nonattainment classifications could be based on the 90th or 95th percentile of daily peak one-hour readings for the area over a rolling three-year period. The current emphasis on the fourth highest daily one-hour maximum concentration of ozone during the most recent three-year period (the design value) often overstates the seriousness of public health risks from ozone. An unusual set of meteorological circumstances can greatly affect this measure and, hence, determine an entire area's attainment status for as long as three years.

*Change the Clean Air Act language that requires primary air quality standards be set at a level to provide an adequate margin of safety against any adverse health consequences. Primary air quality standards should be set to protect the public against "unreasonable" risk of "significant" adverse health effects.*

The EPA's Office of Air Quality Planning and Standards recently recommended that mild responses to ozone -- those involving only a 5 to 10 percent reduction in lung function -- not be considered an "adverse" health effect.<sup>81</sup> Allowing the EPA Administrator to use discretion in defining "significant" adverse health effects seems no more problematic than the current difficulty of defining an "adverse" health effect.

In addition, the EPA Administrator's definition of "unreasonable risk" should be required to take into account the nature and extent of the risk, the number of people exposed, and the attainability of the standard, taking economic and other public interests into account.

Former EPA official Milton Russell recently concluded in his study of ozone for Oak Ridge National Laboratory, "... [T]he way the law [Clean Air Act] is now written, it is almost as if a cancer were equivalent to a cold, one expected cancer were indistinguish-

able from an epidemic, and as much social disruption . . . and economic cost were to be imposed to avoid the one as to avoid the other."<sup>82</sup>

*Require that the EPA Administrator consider cost-effectiveness when promulgating regulations under the Clean Air Act.*

Requiring the EPA to consider the cost-effectiveness of individual measures to improve air quality likely would reduce the number of federally mandated controls and decrease the cost to comply. This provision would also speed the implementation of measures that pass EPA muster, eliminating the practice of local officials making ad hoc decisions to delay programs that are not cost-effective.

*Encourage market approaches to achieve reduced ozone levels.*

The language in the President's proposal calling for marketable permits, emissions trading and allowing for alternative means to replace specific requirements is a step in the right direction.

*Reduce the federal role in specifying precise control measures to be used. Encourage states to use innovative approaches that fit local circumstances in their state implementation plans.*

Because each nonattainment area is unique, greater flexibility is called for than can be achieved if numerous federal mandates are specified. The EPA's role should be more one of "evaluator" of state implementation plans rather than monitor of state compliance with federal proscriptions.

In this regard, too little attention has been given to temporal controls. Because ozone is a daytime phenomenon, requiring sunlight for its formation, changes in work and commuting habits can have a salutary effect on high peak ozone concentrations.

### **Summary**

President Bush's Clean Air Act proposal is likely to provide the momentum needed to amend the Clean Air Act. Many principles in the President's proposal and in the bills drafted by congressional leaders are steps in the right direction. But our analysis of atmospheric ozone -- its health effects and its complex chemical

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nature -- and of the Clean Air Act's provisions for dealing with urban smog, makes it clear that America's resources could be used more effectively.

The foregoing recommendations for revisions to the Clean Air Act would not "trade lives for dollars"; on the contrary, in practice they would result in a higher level of social benefits for Americans but with less economic disruption. We can afford to protect ourselves from unreasonable exposure to unhealthful air pollutants, but it is impossible to create the zero-risk environment implicitly promised in the Clean Air Act.

## **8. APPENDIX**

### **A-1: HEALTH EFFECTS IN THE KRUPNICK-KOPP BENEFITS STUDY**

#### **Human Health Benefits**

Human health effects of ozone have been widely researched. A recent study by Krupnick and Kopp assimilates a number of these medical studies.<sup>83</sup> This report provides estimates of the health benefits associated with various incremental decreases in the ambient ozone concentration. Krupnick and Kopp use a willingness-to-pay method of benefit estimation, and focus upon reductions in acute health effects because these are the only effects that can be quantified.

Because this method increases in accuracy as the information assumptions required of individuals surveyed are reduced, only those studies asking for a direct valuation of decreased health effects are included in Krupnick and Kopp's study. Surveys asking subjects to value various decreases in ozone levels are not very useful; they assume that the subjects know to what extent adverse health effects change with varying levels of ozone. The relationship between ozone concentration and health effects is difficult enough for clinical scientists to determine much less the average citizen.

Krupnick and Kopp apply concentration-response functions to determine the changes in ozone concentration necessary to elicit a particular decrease in health effects. These concentration-response functions are derived from laboratory and field studies conducted by clinicians and epidemiologists. Epidemiological studies analyze large numbers of subjects and link pollution concentrations to observed health effect rates. Since these real world studies cannot control other significant factors, however, they cannot prove causation -- only correlation.

For example, an epidemiological study may show little or no difference in adverse health effects between a non-polluted area and a more polluted one because people in the more polluted area run their air conditioners/filters and do not exercise during times of increased pollution. Therefore, even though the epidemiological study shows that pollution seems to have no effects, this "non-result" may be primarily due to the averting behavior of people in the polluted area.

Clinical studies, on the other hand, do not allow subjects to mitigate their exposure to ozone, but they do control confounding fac-



tors. A problem with some clinical studies is their use of small groups of subjects. These studies control for other influential variables, however, and can therefore demonstrate causation, not just correlation. Clearly it is beneficial to use both of these methods in conjunction with one another to appropriately evaluate the harm caused by smog.

The application of clinical studies to benefit analyses can be criticized because of the exercise factors imposed upon the subjects. Most studies require subjects to exercise at particular rates as measured in liters per minute of air exchange. Obviously, applying the resulting adverse health effects directly to the general population would be a gross overestimation of negative effects.

Krupnick and Kopp account for this problem by deriving a set of exercise factors. They assume the health response is linear with respect to time spent exercising and exercise level. Applying average times that the public spends exercising at various periods during the day (ozone concentrations usually follow a regular pattern throughout the day) helps to better adapt the clinical studies to the general population. Also, health effects for moderate and light exercise during two-hour exposures of elevated ozone are incorporated. Finally, while at rest, people are generally not affected by the ambient ozone levels observed in most cities.

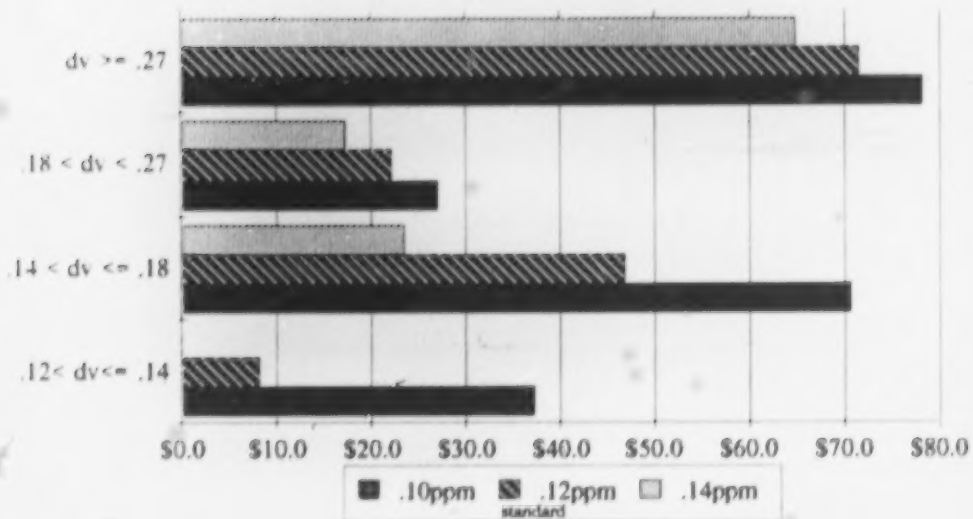
Krupnick and Kopp present seven scenarios for ozone concentration reductions and calculate benefits for each of them. The scenarios include rollbacks to different standards (0.10, 0.12, 0.14 ppm), straight percentage rollbacks (35 percent and 50 percent) and one rollback to 0.12 ppm with a threshold for effects assumed at 0.06 ppm. (All other scenarios assume benefits are derived from reducing ozone concentrations all the way to background levels, usually 0.04 ppm.)

The benefits estimated for each of these scenarios are broken down further by design value categories and geographical grouping. Figures A-1.1 through A-1.3 summarize the total nationwide benefits -- low, mid and high estimates -- by design value and for across-the-board rollbacks to bring all areas within a standard of 0.10, 0.12 or 0.14 parts per million.

Several observations can be drawn from these charts. First of all, in the dirtiest air areas (design values greater than 0.27 ppm), the greatest benefits are derived by getting to the 0.14 ppm level -- from \$65 to \$710 million -- and incremental total dollar gains are smaller for continued improvements. However, total benefits of reaching a standard of 0.10 ppm in areas with moderate problems (0.14 to 0.18 ppm design values) range from \$70 million to \$670 million versus \$47 million to \$490 million for a rollback to 0.12 ppm.

Figure A-1.1

**TOTAL U.S. BENEFITS (LOW ESTIMATE)  
BY DESIGN VALUE AREA  
(millions of 1984 dollars)**



*Source:* Author's calculations from data presented in Alan J. Krupnick and Raymond J. Kopp, *The Health and Agricultural Benefits of Reductions in Ambient Ozone in the United States* (Washington, D.C.: Resources for the Future, Discussion Paper QE88-10, August 1988).

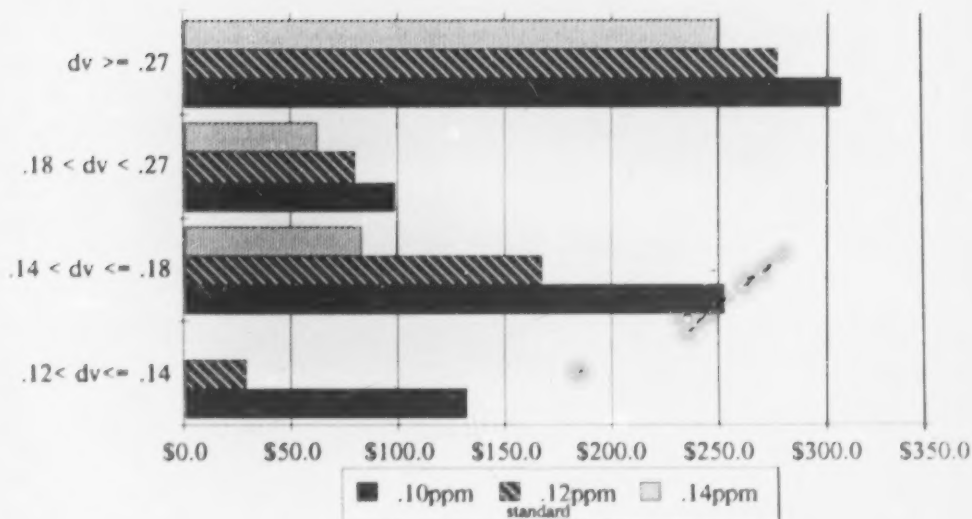
The simple explanation for this phenomenon is that the benefits of reducing ambient ozone pollution from, say, 0.36 ppm to 0.14 ppm, are far greater than the next small reductions of 0.02 and 0.04 ppm. If areas falling in the range of 0.14 to 0.18 ppm have the greatest numbers of people in cities that are in the bottom of this range -- 0.14 or 0.15 -- then reaching a 0.14 ppm standard is not nearly as beneficial as decreasing pollution further to 0.12 or 0.10 ppm.

#### **Distribution of Benefits**

It is important to realize that as the standard is lowered (decreasing ppm allowed) the number of people living in cities out of attainment increases. Therefore, the total benefits certainly increase; however, since lower concentrations of ozone probably pro-

Figure A-1.2

**TOTAL U.S. BENEFITS (MID ESTIMATE)  
BY DESIGN VALUE AREA  
(millions of 1984 dollars)**



*Source:* Author's calculations from data presented in Krupnick and Kopp, 1988.

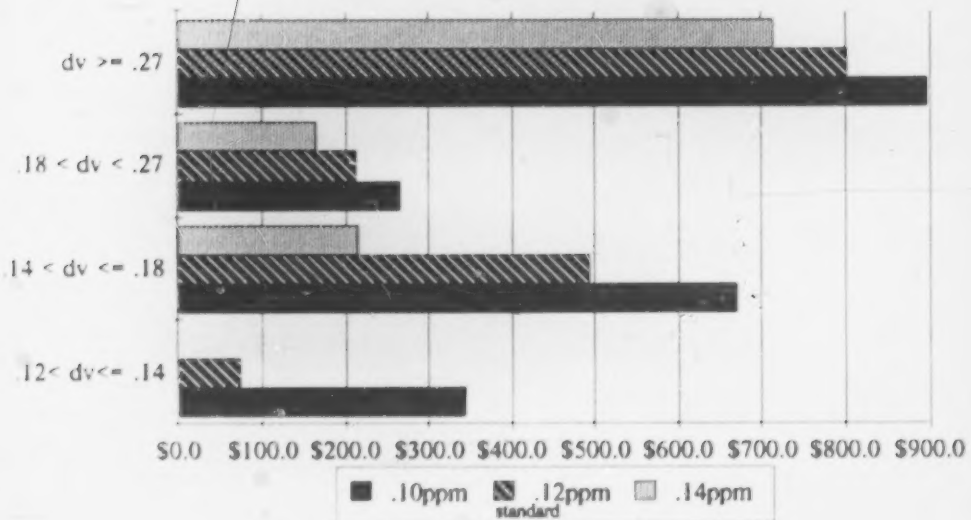
duce fewer health effects, the benefits per person do not necessarily increase.

In Figure A-1.4, mid-range estimates of benefits are divided by the population living within design value areas to arrive at an estimate of per capita benefits. It is clear from this figure that per capita benefits are heavily weighted in favor of those living in the most polluted areas. Los Angeles residents derive \$23.50 of benefits annually from reaching a 0.12 ppm standard. But residents in cities like St. Louis and Phoenix with design values of 0.16 ppm, derive less than \$3.10 in benefits from achieving a 0.12 ppm level. Obviously these estimates are averages; demographics and lifestyle variances across cities are not considered.

Clearly, the benefits of reduced smog to people living in high design value areas are much greater than the benefits to people living in lower design value areas. Moreover, when one considers that the category encompassing areas with design values at and above 0.27 ppm includes only three counties of Los Angeles, it appears that a

Figure A-1.3

**TOTAL U.S. BENEFITS (HIGH ESTIMATE)  
BY DESIGN VALUE AREA  
(millions of 1984 dollars)**



Source: Author's calculations from data presented in Krupnick and Kopp, 1988.

relatively small portion of the total population receives a disproportionate percentage of the benefits.

Specifically, these counties represent 11 percent of the total U.S. population living in nonattainment areas, but they receive more than 50 percent of the total health benefits from arriving at a 0.12 ppm ozone concentration. In fact, even when this highest design value category is averaged with the next lowest category, twenty percent of the population (those people residing in areas with design values greater than 0.18 ppm) receives roughly 65 percent of the total benefits.

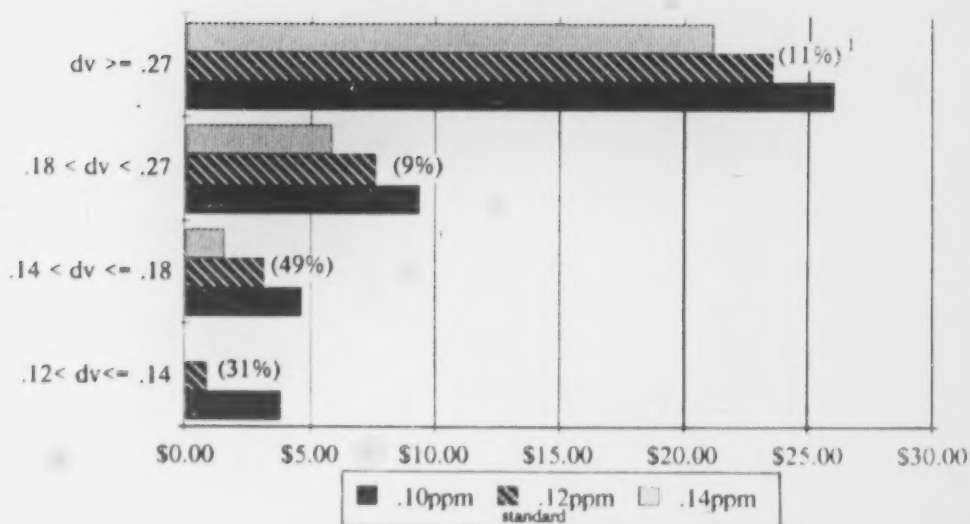
In sum, nearly half of the population living in ozone nonattainment regions receive less than a proportional share of the benefits of reaching the air quality standard for ozone. This is not a terribly surprising result but it does imply that, except for transport regions that significantly pollute their neighbors, programs which incur nationwide costs to reduce regional smog problems should be resisted.

Krupnick and Kopp have done a tremendous job of providing estimates of benefits for lowered levels of ozone based upon current



Figure A-1.4

**BENEFITS PER PERSON (MID ESTIMATE)  
BY DESIGN VALUE AREA  
(1984 dollars)**



<sup>1</sup> Numbers in parentheses show the percent of the nonattainment population residing in that design-value group.

Source: Author's calculations from data presented in Krupnick and Kopp, 1988.

medical knowledge and a willingness-to-pay approach. If recent concerns about longer term health effects prove to be significant, however, these estimates would understate benefits.

The EPA is conducting two studies to determine the probable cost of chronic effects due to elevated ozone levels. Although the studies are still not completed, researchers state that of the 7.5 percent of the population that experience chronic respiratory problems (emphysema, asthma, and chronic bronchitis), at least 80 percent of these cases directly result from tobacco smoking. Other pollutants such as  $SO_2$  and particulate matter are responsible for a large portion of the remaining cases.

Nevertheless, these added health concerns warrant caution in using cost-benefit analysis. They do not, however, justify ignoring altogether the information that can be gained from this technique.

## A-2: COMPARISON OF LEADING LEGISLATIVE PROPOSALS

Table A-2.1

### MAJOR OZONE PROVISIONS OF KEY BILLS

| H.R. 2323 (The Waxman Bill)                                                                                                                                                                                                                                                                            | H.R. 99 (The Group of Nine Bill)                                                                                                                                                                                                                                                                                                                                                | (The Bush Proposal)                                                                                                                                                                                                                                                                                                              |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>I. Classification of Nonattainment Areas</b></p> <p>Establishes 4 categories of nonattainment areas including Moderate, Serious, Severe, and Extreme. The classification is based upon the percentage that an area's design value exceeds the national primary ambient air quality standard.</p> | <p>Establishes 4 categories of nonattainment areas including Moderate Class I, Moderate Class II, Serious, and Severe. This classification is based upon the percentage that an area's design value exceeds the national primary ambient air quality standard.</p>                                                                                                              | <p>Establishes 4 categories of nonattainment areas including Marginal, Moderate, Serious and Severe. These classifications are based upon an area's design value for ozone. (For comparison to other bills, we have converted these values to a percentage exceedance of the national primary ambient air quality standard.)</p> |
| <p><b>II. New Attainment Deadlines</b></p> <p>Requires attainment in 4, 8, 12, and 16 years after enactment for Moderate, Serious, Severe, and Extreme areas respectively.</p>                                                                                                                         | <p>Requires attainment 3 years after enactment and 3, 5, and 13 years after approval of SIP revision for Class I, Class II, Serious, and Severe areas respectively. The revision of the SIP is due 7/1/91, but regardless of approval date, the attainment date can not be later than 12/31/95, 12/31/97, and 12/31/05 for Class II, Serious and Severe areas respectively.</p> | <p>Requires attainment by 12/31/95 for Marginal and Moderate nonattainment areas, by 12/31/2000 for Serious areas, and "as expeditiously as practicable" but no later than 12/31/10 for Severe areas.</p>                                                                                                                        |

Table A-2.1 (continued)

H.R. 2323 (The Waxman Bill)

III. Monitoring Performance

Administrator calculates the percentage reduction in VOCs necessary for an area to meet the primary ozone standard. Intermediate emission reduction milestones are also set. Milestones are to be met every four years that an area is working toward its attainment deadline. The bill sets minimum emissions reduction levels for each classification. The SIPs must contain specific control measures outlined and these measures become increasingly stringent as the classification level increases.

H.R. 99 (The Group of Nine Bill)

The Administrator calculates the percentage reduction in VOCs necessary for an area to meet the primary ozone standard based upon the design value for the area on 12/31/87. At any time the Administrator determines that an area will not meet the proposed attainment deadline, the Administrator may reclassify the area. Attainment deadlines for reclassified areas are not as long as for areas originally in the classification. SIPs must contain the specific control measures outlined and these measures become increasingly stringent as the classification level increases.

(The Bush Proposal)

The Administrator must classify an area based upon its 1988 design value. The EPA may adjust the classification of an area whose design value is within 5 percent of the classification cutoff. Intermediate VOC emission reductions are required until either the attainment deadline or attainment occurs (whichever is first). Controlling NO<sub>x</sub> emissions may decrease required VOC reductions. The Administrator may reclassify an area, and this area must meet all proposed deadlines for areas originally in the classification. SIPs must contain specific control measures (except for special cases), and these measures become increasingly stringent as the classification level increases.

IV. Control Measure Requirements

A. Areas 20% or less over the standard

Moderate (20% over standard or less).

Areas must meet existing requirements plus the following:

- Permit program for sources emitting at least 25 tons per year (tpy) VOC or NO<sub>x</sub>.
- Offset ratio for these sources must be at least 1.2:1.

Moderate Class I (15% over standard or less).

Areas must meet existing requirements plus the following:

- Permit program for all sources emitting VOC or NO<sub>x</sub>.
- Offset ratio for all new, modified, or existing sources must be at least 1.2:1.
- Emissions resulting from modifications in ex-

Marginal (design value of 0.13 ppm [8.3% over standard or less]).

Areas must meet the following requirements:

- Submit a comprehensive inventory of emissions from all sources within 2 years after enactment, and again by 9/30/90 and each 3-year period thereafter.
- Implement those RACT that were required immediately before enactment of this bill.

H.R. 2323 (The Waxman Bill)

Table A-2.1 (continued)  
H.R. 99 (The Group of Nine Bill)

(The Bush Proposal)

isting sources shall not be considered "de minimis" unless the increased emissions do not exceed a total of 25 tons over any period of five consecutive years.

- B. Areas between 15 and 25% but not covered in (A) or (C)

No applicable classification.

- Revise the I/M plan to include provisions to adequately support an I/M program as stringent as either that already defined in the plan or that in House Report No. 95-294; whichever is strictest.

Moderate Class II (15 to 25% over standard).

Areas must meet all applicable requirements for Moderate Class I areas and all of the following:

- Offset ratios for the permit program must be at least 1.2:1 for sources seeking offsets of 50 to 100 tpy, but for offsets of more than 100 tpy the ratio must be at least 1.5:1.
- The above offset ratios do not apply to  $\text{NO}_x$  where the Administrator determines that decreasing these emissions will be deleterious to air quality.
- All RACT for the control of VOCs shall be applied to stationary sources.
- Those sources emitting 50 tpy VOC or more (lower threshold may be instituted by the Administrator) must follow the CTG for their source once the Administrator has issued an applicable CTG.

Moderate (design value of 0.14-0.15 ppm [16.7 to 25% over standard]).

Areas must meet all applicable requirements for Marginal areas plus the following:

- No later than 3 years after enactment the state must submit its revised SIP plan.
- By 12/31/95 baseline emissions must fall by at least 15 percent, taking into account growth in emissions. This reduction cannot include evaporative emissions measures in effect before passage of this bill. Additionally, it cannot include reductions from fuel volatility regulations or I/M programs already in place.
- Each source category covered by a CTG, issued after enactment but before attainment, must implement the accompany RACT.
- By 5/31/95 each source category covered by any CTG issued before enactment shall in-



Table A-2.1 (continued)

H.R. 2323 (The Waxman Bill)

H.R. 99 (The Group of Nine Bill)

(The Bush Proposal)

\*I/M program in compliance with emission standards detailed in mobile source requirements.

still the appropriate RACT. All stationary sources potentially emitting at least 100 tpy of VOCs shall implement RACT by this deadline also.

\*Stage II gasoline vapor recovery systems must be implemented at all gasoline stations according to the following schedule (except where the Administrator exempts small stations):

- 6 months after adoption of plan for facilities constructed after enactment.
- 1 year after adoption for stations dispensing at least 100,000 gallons a month.
- 2 years after adoption for all other stations.

C. Areas between 20 and 50% over the standard

Serious (20 to 50% over standard).

Areas must meet existing requirements plus the following:

- \*Permit program covers, in addition to stationary sources emitting at least 25 tpy, construction or operation of each new or modified emissions unit that is part of a source potentially emitting at least 25 tpy VOC or NO<sub>x</sub>.
- \*No emissions are to be considered "de minimis" unless the total source's emissions are not greater than 10 tpy.
- \*After 4 years the area must meet a milestone

Serious (25 to 50% over standard).

Areas must meet applicable requirements for Moderate Class II areas plus the following:

- \*Offset ratios for the permit program must be at least 1.5:1 for sources emitting 50 tpy or more.
- \*The above offset ratios shall not apply to NO<sub>x</sub> where the Administrator determines that decreasing these emissions will be deleterious to air quality.
- \*In addition to applying RACT for VOCs, all sources emitting at least 25 tpy in this area shall apply RACT for NO<sub>x</sub> emissions.

Serious (design value of 0.16-0.18 ppm [33.3 to 50% over standard]).

Areas must meet existing requirements for Moderate areas plus the following:

- \*SIP plan must show attainment by applicable date using photochemical grid modeling or another method the Administrator deems as effective.
- \*In addition to the 15% emission reduction required by 1995, areas must meet further baseline emissions reductions of 3% per year, averaged over each consecutive rolling 3-year period beginning 1/1/96, until attainment.

## H.R. 2323 (The Waxman Bill)

reduction of at least 20% of emissions inventory from base year 1988.

- The Administrator's reduction requirement must be at least 30% of inventory.
- Offset ratios must be at least 1.3:1.
- Required I/M program
  - covers light duty vehicles
  - covers MSAs with populations of at least 100,000 (1985 census)
  - annual emissions testing and direct inspection of equipment
  - waiver of repair for costs greater than \$200, but a lower waiver may apply to costs not covered by a warranty.
- Stage II vapor recovery system
  - applies to all facilities selling more than 10,000 gallons/month gasoline or 50,000 gallons/month for independent small businesses.
  - revise or waive requirements after on-board emissions controls are in widespread use.
- Low emissions transit buses
- Existing sources emitting at least 50 tpy of VOC or NO<sub>x</sub> must obtain operating permits from the state within 2.5 years after enactment.

## Table A-2.1 (continued) H.R. 99 (The Group of Nine Bill)

- Those sources emitting at least 50 tpy must follow the CTG set for their source once the Administrator has established an applicable CTG.
- Five-year operating permits shall be required for sources emitting at least 25 tpy VOC or NO<sub>x</sub>. Permits require annual review.
- Stage II vapor recovery systems.
  - applies to all facilities selling more than 10,000 gallons/month gasoline (50,000 gallons/month for small independent business marketers).
- Enhanced monitoring and enforcement.
- Enhanced I/M in accordance with the mobile source requirements.
- Increase the percentage of low emission vehicles (VOC and NO<sub>x</sub>) based on guidelines published by the Administrator, OR
- Implement a transportation control program that results in at least equivalent reductions in emissions.
- Fleets of at least 15 vehicles, that have or could have centrally located refueling stations or publicly available alternative fuel, must meet the following requirements for the percentage of new, low emission vehicles purchased in the applicable year:
  - 1994 = 30%
  - 1995 = 50%
  - 1996 and beyond = 90%

## (The Bush Proposal)

- amounts less than 3% may be satisfactory if the Administrator determines that all feasible measures are already in effect or that less than 3% reduction is necessary to meet attainment.
- NO<sub>x</sub> controls may substitute for VOC abatements if ozone levels can be reduced by as much or more by so doing.
- Enhanced I/M program (for areas with a population of 200,000 or more) in accordance with mobile source requirements.
  - includes computerized emissions analysis.
  - no waivers for parts covered by emissions warranty
  - waivers of repair shall not be less than \$75 for pre-1981 vehicles, and less than an initial \$200 for 1981 and later model years. The subsequent period's waiver shall be at least \$75.
- If at any time the Administrator determines that the area's level of vehicle miles traveled exceeds projections, the state must revise the SIP to include a transportation demand management program to reduce vehicle miles and congestion.
  - the state may offset this requirement by implementing transportation control measures, other mobile source controls, or controls on other source categories.

Table A-2.1 (continued)

H.R. 2323 (The Waxman Bill)

H.R. 99 (The Group of Nine Bill)

(The Bush Proposal)

\*States must adopt a clean fuels program or specify other new measures that will achieve equivalent long-term reduction in emissions for areas with more than 250,000 residents and a 1988 design value of 0.18 ppm or above.

\*All new or newly purchased buses for fleets of 10 or more must be low emission buses after 1989.

\*All new or newly purchased buses for fleets of 10 or more must be low emission buses after 1989.

D. Areas 50 to 100% over the standard

Severe (50 to 100% over standard).

Severe nonattainment areas (50% and above).

Severe (design value 0.19 ppm and above [58.3% and above]).

Areas must meet all existing measures, all applicable measures for Serious areas, and the following:

- \*The Administrator's emission reduction requirement must be at least 50% of the inventory.
- \*Permits are required for sources emitting at least 10 tpy VOC or NO<sub>x</sub>.
- \*All offset ratios must be at least 1.5:1.
- \*At least 30% of new vehicles registered or operating primarily in the area must be low emission vehicles by 1998.
- \*Existing sources emitting at least 25 tpy VOC or NO<sub>x</sub> may not trade emissions to comply with RACT.
- \*Each fuel tank installed after approval of SIP shall be capable of storing methanol fuel.

Areas must meet all applicable requirements for Serious areas plus the following:

- \*The offset ratio of 1.5:1 shall apply to all sources emitting at least 25 tpy VOC or NO<sub>x</sub>.
- \*The exemption for no available alternative fuel or vehicle shall not apply to fleet vehicles.
- \*Transportation control measures shall be implemented once the Administrator has published the applicable guidelines
- \*Stationary sources emitting 25 tpy or more, but not achieving the lowest achievable emissions nor obtaining offsets from other sources, must reduce emissions by 9% each 3 year period after 1989 or the year after the area is reclassified as Severe.
- \*Owners or operators of sources failing to comply with any emission reductions are subject to a civil penalty of \$2,000/ton of VOC emitted per year.

Areas must meet all applicable requirements for Serious areas plus the following:

- \*A fee of \$5,000 per ton of VOC emitted must be applied to major stationary sources if the area fails to meet the attainment deadline.
- fee applies only to the extent the source fails to reduce its emissions by 20% following the attainment deadline.
- fee does not apply if ozone transport is the reason for nonattainment and all other requirements have been met.

Table A-2.1 (continued)

(The Bush Proposal)

H.R. 99 (The Group of Nine Bill)

H.R. 2323 (The Waxman Bill)

\*SIPs must have provisions prohibiting the expenditure of federal funds for transport unless the transportation planning for the area includes all RACT for reducing aggregate vehicle emissions.

\*All new vehicles for fleets of at least 15 must use low emission fuels when operating in the area.

-does not apply to fleets that do not and can not have central refueling stations unless low-polluting fuels are widely available at retail fuel outlets.

\*Additional emission reduction milestones, to be set by the Administrator, must be met eight years after enactment.

E. Areas more than 100% over the standard

Extreme nonattainment areas (more than 100% over standard)

Areas must meet all existing measures, all applicable measures for Severe areas, and all of the following:

\*The Administrator's emission reduction requirement must be at least 70% of the inventory.

\*Existing sources emitting at least 10 tpy VOC or NO<sub>x</sub> must obtain permits from the state.

Not a separate designation, still falls under Severe nonattainment area.

Not a separate designation, still falls under Severe nonattainment area.



Table A-2.1 (continued)  
H.R. 99 (The Group of Nine Bill) (The Bush Proposal)

H.R. 2323 (The Waxman Bill)

\*All new, modified, or existing electric utilities and industrial and commercial boilers emitting more than 25 tpy of VOC or NO<sub>x</sub> must burn as their primary fuel natural gas, methanol, ethanol, or another clean fuel, OR they must use advanced control technology such as catalytic scrubbers, for reduction of NO<sub>x</sub> within 8 years after enactment of the bill

\*The following percentages of newly registered vehicles must be low emission vehicles:  
1994 = 10%  
1996 = 30%  
1998 = 70%  
2000 = 100%

\*Heavy traffic hours may have control measures to reduce high polluting vehicles operating during that time.

V. Failure to Implement SIP

\*No highway funds will be approved other than those specified for mass transit, improvement of air quality, or correction of a safety hazard.

\*Offsets applied must have at least a 3:1 ratio.

\*Prohibit construction and modification of stationary sources potentially emitting 50 tpy VOC or NO<sub>x</sub>.

\*Prohibit any public water system from providing service to people not serviced prior to the state's failure to fully implement its SIP.

\*The Administrator must propose to apply at least one of the following sanctions:  
-ban on construction or modification of any stationary source emitting 100 tpy VOC or NO<sub>x</sub> within 25 miles of the area's boundary.  
-ban on drinking water hookups.  
-withholding air pollution grants.

H.R. 2323 (The Waxman Bill)

Table A-2.1 (continued)

H.R. 99 (The Group of Nine Bill)

(The Bush Proposal)

- \*Secretary of Transportation may disapprove projects and awards other than those used for mass transit, safety, or air quality management.
- \*Assess a penalty against owners and operators of sources emitting at least 25 tpy VOC.
- \*The Administrator may enforce a civil penalty of \$2,000/ton VOC emitted annually against the owner or operator of any source emitting more than 25 tpy regardless of the source's compliance with other laws.

- \*The EPA may promulgate a federal implementation plan.
- \*Permits cannot be issued under approved permit plan.

VI. Failure to Meet Milestones

All areas are reclassified as the next classification (Moderate to Serious, Serious to Severe, and Severe to Extreme). Deadlines may be adjusted for a limited period if the area is reclassified.

OR

Serious areas may, within 90 days after failing to meet the milestone, implement additional measures to bring them into milestone attainment. Severe areas may implement programs using economic incentives as defined in the bill.

No milestones in this bill.

Although there are no "milestones," there is a similar "reasonable further progress" requirement. Not meeting these requirements can lead to sanctions or reclassification.

Table A-2.1 (continued)

H.R. 2323 (The Waxman Bill)

H.R. 99 (The Group of Nine Bill)

(The Bush Proposal)

VII. Failure to Achieve Attainment

- \*Moderate, Serious and Severe areas are reclassified to the next nonattainment level. Deadlines are then set as those already applying to other areas with the same classification. Milestone deadlines may be adjusted for a limited time.
- \*Extreme areas must do the following:
  - set offset ratios to at least 3:1.
  - implement economic incentives as defined in the bill except that these programs should be designed to reduce VOC and NO<sub>x</sub> by 5% per year.

- \*The same sanctions as those for "failure to implement SIP" if the area did not meet the standard because of inadequate implementation.
- \*Class I, Class II, and Serious nonattainment areas are reclassified to the next nonattainment level, new SIPs must be submitted within 12 months, and these SIPs must contain the requirements for that new classification.
- \*Severe nonattainment areas must submit a new SIP within 12 months, and this plan must contain the following:
  - no new stationary sources potentially emitting at least 25 tpy of VOC or NO<sub>x</sub> may be constructed or modified unless they meet offsets of at least 2:1.

- \*States must revise SIP to include additional measures prescribed by Administrator.
  - these must be all measures that can be feasibly implemented in light of costs, technology, and other health and environmental impacts.
- \*Marginal, Moderate, and Serious nonattainment areas are reclassified to the next nonattainment level or the classification applicable to the area's design value, and deadlines for that new level are applied.
- \*Severe nonattainment areas must resubmit a SIP that charges a fee of \$5,000 per ton of VOC emissions to major sources. The fee applies only to the extent the source fails to reduce its emissions by 25% following the attainment deadline.
  - this does not apply to areas whose populations are under 200,000 and whose nonattainment is the result of ozone transport.

VIII. Mobile Standards

- \*Emissions from gasoline and diesel-fueled vehicles and trucks may not exceed HC emission standards set below (in grams per mile):
 

|                          |           |          |
|--------------------------|-----------|----------|
|                          | 1993-1999 | 2000 +   |
| light duty vehicles      | .25 gpm   | .125 gpm |
| trucks (3750-10,000 lbs) | .5 gpm    | .5 gpm   |

- \*HC emission standards for gasoline-fueled passenger cars and light duty trucks built in model year 1993 and thereafter must respectively meet .25 gpm and .5 gpm standards in the following percentages:

- \*Urban buses operating primarily in metropolitan areas, whose population is over 1,000,000, must be capable of operating, and exclusively operated, on clean alternative fuel.

Table A-2.1 (continued)

H.R. 2323 (The Waxman Bill)

\*The Administrator shall evaluate and revise (if technology allows) the above standards at least every 4 years.

\*New non-road-use engines with horsepower greater than or equal to 50 must meet standards for HC emissions by 1/1/93. These standards must be at least comparable to those set for on-road mobile sources with the closest horsepower. Aircraft engines are exempt.

\*Light duty vehicles manufactured after 1992 must meet an idle test certification (to be set by Administrator).

\*For purposes of sampling inspection, no more than 10% of vehicles may fail selective enforcement audits after model year 1990.

\*Within 18 months after enactment, the Administrator will revise test procedures to ensure that vehicles are tested under circumstances reflecting actual driving conditions:

- fuel volatility
- temperature and altitude
- acceleration.

These procedures must test for evaporative running losses in addition to tailpipe. These standards take effect in the second model year after that year.

\*Each type vehicle sold must meet emission standards. No longer will manufacturers be allowed to average emissions.

H.R. 99 (The Group of Nine Bill)

|      |   |      |
|------|---|------|
| 1993 | = | 30%  |
| 1994 | = | 60%  |
| 1995 | = | 90%  |
| 1996 | = | 100% |

The remaining vehicles built in 1993-95 must meet 1992 standards. From 1992-1998, the Administrator may apply 1992 standards in lieu of the above for determining conformity percentages.

\*Within 18 months after enactment, the Administrator will set idle test regulations. Engines made in model year 1993 and thereafter must pass this for certification.

\*By 1/1/92, the Administrator must undertake a study to determine each of the following:

- effect of fuel composition on meeting in-use standards, and the time necessary to implement such improvements.
- the extent to which I/M programs assure in-use standards are met, and whether or not a nationwide program would be effective.

-owner maintenance effects on meeting in-use standards.

-technical feasibility of vehicles meeting in-use standards during their useful life.

\*Based on the above study, the Administrator will set fuel composition standards, I/M program rules, maintenance schedules as condi-

(The Bush Proposal)

-this program is to be phased in over 1991-1994 model years, but may be postponed for up to 2 years.

\*A specified number of cars and light-duty trucks capable of operating on clean alternative fuels must be sold in the most serious nonattainment areas (1988 design value at or above 0.18 ppm whose population is above 250,000).

These vehicles must emit "substantially less" (determined by Administrator) VOCs than do conventionally fueled vehicles.

-clean fuels must be available in the areas where these vehicles are sold.

-the following schedule of manufacture, sale and distribution must be followed:

|           |   |                    |
|-----------|---|--------------------|
| 1995      | = | 500,000            |
| 1996      | = | 750,000            |
| 1997-2004 | = | 1,000,000 each yr. |

-automakers may be granted transferable emissions credits for vehicles emitting less than Administrator's standards or production of more vehicles than scheduled, or heavy-duty trucks capable of operating on clean fuels.

-a designated nonattainment area may "opt out" of the clean-fuel program if it implements new measures that achieve equivalent benefits.



Table A-2.1 (continued)

H.R. 2323 (The Waxman Bill)

\*Any person who tampers with engine pollution control devices or sells a component whose primary function is to bypass these systems shall be subject to a civil penalty.

\*Motorcycles must meet the following standards for HC emissions in 1992 and thereafter:

Engine less than 700 cc = 2.0 gpm  
Engine more than 700 cc = 3.6 gpm

\*Vehicles manufactured the second model year after the model year in which the mobile source procedures and standards are set (by the Administrator) must include onboard diagnostic equipment that tests the effectiveness of the emissions control systems.

\*Gasoline sold during high ozone periods of each year shall not exceed a RVP of 9.0 psi (in Class C areas). The Administrator may lower this standard.

-the high ozone period is May 16-September 15 or longer for certain regions

-oxygenated fuel may have an RVP of 1 psi greater than that set for non-oxygenated gasoline.

\*All new light duty motor vehicles, manufactured in or after the second model year after that in which the standards are set, must be equipped with onboard vapor recovery systems

H.R. 99 (The Group of Nine Bill)

tions on manufacturer's warranties, and revised in-use emission standards (at least as stringent as 1992 standards).

\*Within 2 years after enactment, the Administrator will determine whether or not a nationwide I/M program for heavy duty trucks and buses should be implemented.

\*Any person tampering with or selling equipment whose primary purpose is to bypass emission control equipment shall be subject to a civil penalty.

-this does not apply to conversion of a vehicle from gasoline to natural gas as its power source, provided that the new engine conforms to standards set by the Administrator by 10/31/89.

\*NO<sub>x</sub> and VOC emissions standards for non-road engines shall be set by 1/1/91. Standards require greatest reduction considering the cost of application within time period for meeting standard, energy, safety, and noise. Standard effective at the earliest date appropriate considering costs, safety, etc.

\*If the Administrator sets standards that do not require onboard vapor recovery systems, all nonattainment areas must use Stage II technology.

\*If Stage II technology is required without onboard devices, the manufacturer of each new light duty vehicle must pay a fee for each new

(The Bush Proposal)

-the Administrator may require that clean fuels be available along major nationwide transportation corridors.

\*Emissions of non-methane hydrocarbons from light-duty automobiles and engines must not exceed 0.25 grams per mile for the following percent of vehicles and model years:

1993 = 40%  
1994 = 80%  
1995 and later = 100%

\*Emissions of hydrocarbons from light-duty trucks must not exceed 0.41 grams per mile for 50% of 1994 model year vehicles and 100% of 1995 and later model years.

\*Emissions of hydrocarbons from heavy duty (more than 3,750 lbs.) trucks may not exceed 0.50 grams per mile for 1994 model years and beyond.

\*The Administrator may promulgate regulations applicable to evaporative hydrocarbon emissions from all gasoline-fueled motor vehicles under "ozone-prone summertime conditions."

\*After consideration of environmental benefits and economic factors, the Administrator may require installation of pollution control diagnostic systems in all new motor vehicles.

\*The Administrator will revise vehicle certification tests to reflect in-use conditions.

Table A-2.1 (continued)

H.R. 2323 (The Waxman Bill)

to control evaporative emissions during refueling. The minimum capture efficiency shall be 95%.

•The Administrator shall conduct audits (every 2 years) of I/M programs in effect in areas classified as Severe or Extreme.

H.R. 99 (The Group of Nine Bill)

vehicle. This money will be used to fund the full cost of the Stage II system.

•Fuel volatility standards must be set within 1 year after enactment. If not set, the standard will automatically be set at an RVP of 9.0 during the period May 15 to September 15 each year (except in Class C areas [defined by ASTM] where the standard will be June 15 to September 15).

•Certification fuels must have the same volatility as that of gasoline in common use.

(The Bush Proposal)

-the Administrator may allow fleet averaging.

•To avoid recall, vehicles must maintain their emission reduction capabilities according to a complicated schedule specified in the proposal.

•By 1992, all fuel sold during the ozone season may not exceed a RVP of 9 psi (in Class C areas).

•Gasoline containing at least 9 but no more than 10 percent ethanol may exceed the RVP limit by 1 psi.

•Alternative controls are allowed for fuel vapor recovery if they reduce emissions by at least as much as the regulations required for the area.

•Individuals tampering with or selling parts to disable any emission control system are subject to a maximum civil penalty of \$25,000 for each offense (or up to \$200,000 total).

# KEY TO ABBREVIATIONS:

|      |   |                                         |
|------|---|-----------------------------------------|
| ASTM | = | American Society for Testing Materials  |
| CTG  | = | control technique guideline             |
| gpm  | = | grams per mile                          |
| HC   | = | hydrocarbons                            |
| I/M  | = | inspection/maintenance                  |
| LDT  | = | light duty truck                        |
| MSA  | = | metropolitan statistical area           |
| psi  | = | pounds per square inch                  |
| RACT | = | reasonably available control technology |
| RVP  | = | Reid Vapor Pressure                     |
| SIP  | = | state implementation plan               |
| tpy  | = | tons per year                           |
| VOC  | = | volatile organic compound               |

### A-3: NONATTAINMENT AREAS, 1986-1988 DATA

Table A-3.1

#### URBAN EMISSION REDUCTIONS NEEDED TO REACH OZONE ATTAINMENT

| Area                                    | Population<br>(millions) | 1986<br>-1988<br>design<br>value | Percent<br>above<br>standard | NMOC/<br>NO <sub>x</sub><br>ratio | Required<br>VOC<br>reductions<br>(%) |
|-----------------------------------------|--------------------------|----------------------------------|------------------------------|-----------------------------------|--------------------------------------|
| Los Angeles, CA                         | 8.3                      | .34                              | 183%                         | 10.4                              | 80%                                  |
| New York City, NY                       | 8.5                      | .22                              | 83%                          | 11.7                              | 67                                   |
| Chicago, IL                             | 6.2                      | .20                              | 67%                          | 7.8                               | 53                                   |
| Houston, TX                             | 3.2                      | .19                              | 58%                          | 10.9                              | 60                                   |
| Baltimore, MD                           | 2.9                      | .18                              | 50%                          | 7.1                               | 42                                   |
| Hartford, CT                            | 0.7                      | .18                              |                              | 9.4                               | 53                                   |
| Milwaukee, WI                           | 1.4                      | .18                              |                              | 9.6                               | 53                                   |
| Muskegon, MI                            | 0.2                      | .18                              |                              | 12.2                              | 61                                   |
| Philadelphia, PA                        | 4.5                      | .18                              |                              | 7.2                               | 43                                   |
| Portsmouth-Dover,<br>NH-ME <sup>1</sup> | 0.2                      | .18                              |                              | 12.2                              | 38                                   |
| San Diego, CA                           | 2.4                      | .18                              |                              | 7.4                               | 44                                   |
| Atlanta, GA                             | 2.6                      | .17                              | 42%                          | 6.5                               | 36                                   |
| Boston, MA <sup>1</sup>                 | 2.8                      | .17                              |                              | 5.7                               | 34                                   |
| El Paso, TX                             | 0.6                      | .17                              |                              | 8.5                               | 46                                   |
| Fresno, CA                              | 0.6                      | .17                              |                              | 12.2                              | 55                                   |
| Huntington-Ashland,<br>WV-KY            | 0.3                      | .17                              |                              | 12.2                              | 58                                   |
| Louisville, KY                          | 1.0                      | .17                              |                              | 12.2                              | 58                                   |
| Parkersburg-Marietta,<br>WV-OH          | 0.2                      | .17                              |                              | 12.2                              | 58                                   |
| Sheboygan, WI                           | 0.1                      | .17                              |                              | 12.2                              | 58                                   |
| Worcester, MA                           | 0.4                      | .17                              |                              | 12.2                              | 58                                   |
| Bakersfield, CA                         | 0.5                      | .16                              | 33%                          | 12.2                              | 49                                   |
| Baton Rouge, LA                         | 0.5                      | .16                              |                              | 14.8                              | 60                                   |
| Beaumont and<br>Port Arthur, TX         | 0.4                      | .16                              |                              | 22.4                              | 72                                   |

Table A-3.1 (continued)

| Area                                   | Population<br>(millions) | 1986<br>-1988<br>design<br>value | Percent<br>above<br>standard | NMOC/<br>NO <sub>x</sub><br>ratio | Required<br>VOC<br>reductions<br>(%) |
|----------------------------------------|--------------------------|----------------------------------|------------------------------|-----------------------------------|--------------------------------------|
| Cincinnati, OH                         | 1.4                      | .16                              | 33%                          | 9.1                               | 44                                   |
| Dallas-Ft. Worth, TX                   | 2.4                      | .16                              |                              | 9.1                               | 44                                   |
| Portland, ME                           | 0.2                      | .16                              |                              | 11.6                              | 52                                   |
| Providence, RI                         | 0.6                      | .16                              |                              | 12.2                              | 54                                   |
| Sacramento, CA                         | 1.3                      | .16                              | 25%                          | 9.6                               | 45                                   |
| Springfield, MA                        | 0.2                      | .16                              |                              | 12.2                              | 53                                   |
| St. Louis, MO                          | 2.4                      | .16                              |                              | 10.7                              | 50                                   |
| Washington, D.C.                       | 3.6                      | .16                              |                              | 9.2                               | 45                                   |
| Charlotte, NC                          | 1.1                      | .15                              | 25%                          | 10.4                              | 43                                   |
| Cleveland, OH                          | 1.8                      | .15                              |                              | 7.5                               | 33                                   |
| Greensboro and<br>Winston-Salem, NC    | 0.9                      | .15                              |                              | 12.2                              | 47                                   |
| Memphis, TN                            | 1.0                      | .15                              |                              | 13.9                              | 51                                   |
| Pittsburgh, PA                         | 2.1                      | .15                              | 17%                          | 7.8                               | 35                                   |
| Portland, OR and<br>Vancouver, WA      | 1.1                      | .15                              |                              | 9.6                               | 42                                   |
| Visalia, Tulare and<br>Porterville, CA | 0.3                      | .15                              |                              | 12.2                              | 42                                   |
| Allentown-Bethlehem,<br>PA             | 0.7                      | .14                              |                              | 12.2                              | 38                                   |
| Atlantic City, NJ                      | 0.3                      | .14                              | 17%                          | 12.2                              | 38                                   |
| Birmingham, AL                         | 0.9                      | .14                              |                              | 9.1                               | 31                                   |
| Canton, OH                             | 0.4                      | .14                              |                              | 12.2                              | 38                                   |
| Charleston, WV                         | 0.3                      | .14                              |                              | 12.2                              | 38                                   |
| Dayton, OH                             | 0.9                      | .14                              | 17%                          | 12.2                              | 38                                   |
| Detroit, MI                            | 4.3                      | .14                              |                              | 7.8                               | 27                                   |
| Grand Rapids, MI                       | 0.6                      | .14                              |                              | 12.2                              | 38                                   |
| Greenville-Spartanburg,<br>SC          | 0.6                      | .14                              |                              | 12.2                              | 38                                   |
| Harrisburg, PA                         | 0.6                      | .14                              | 17%                          | 12.2                              | 38                                   |
| Knoxville, TN                          | 0.6                      | .14                              |                              | 12.2                              | 38                                   |



Table A-3.1 (continued)

| Area                            | Population<br>(millions) | 1986-<br>1988<br>design<br>value | Percent<br>above<br>standard | NMOC/<br>NO <sub>x</sub><br>ratio | Required<br>VOC<br>reductions<br>(%) |
|---------------------------------|--------------------------|----------------------------------|------------------------------|-----------------------------------|--------------------------------------|
| Miami, FL                       | 1.8                      | .14                              | 17%                          | 13.3                              | 41                                   |
| Modesto, CA                     | 0.3                      | .14                              |                              | 12.2                              | 42                                   |
| Montgomery, AL                  | 0.3                      | .14                              |                              | 12.2                              | 38                                   |
| Nashville, TN                   | 0.9                      | .14                              |                              | 12.2                              | 38                                   |
| Owensboro, KY                   | 0.1                      | .14                              |                              | 12.2                              | 38                                   |
| Phoenix, AZ                     | 1.6                      | .14                              |                              | 9.6                               | 31                                   |
| Poughkeepsie, NY                | 0.3                      | .14                              |                              | 12.2                              | 38                                   |
| Raleigh-Durham, NC              | 0.3                      | .14                              |                              | 12.2                              | 38                                   |
| Reading, PA                     | 0.3                      | .14                              |                              | 12.2                              | 38                                   |
| Richmond, VA                    | 0.8                      | .14                              |                              | 11.3                              | 37                                   |
| Salt Lake City, UT              | 1.0                      | .14                              |                              | 10.3                              | 35                                   |
| San Francisco, CA <sup>1</sup>  | 1.6                      | .14                              |                              | 9.6                               | 44                                   |
| Toledo, OH                      | 0.6                      | .14                              |                              | 12.2                              | 38                                   |
| Albany-Schenectady-<br>Troy, NY | 0.8                      | .13                              | 8%                           | 12.2                              | 24                                   |
| Altoona, PA                     | 0.1                      | .13                              |                              | 12.2                              | 24                                   |
| Anderson, SC <sup>2</sup>       | 0.1                      | .13                              |                              | 12.2                              | 24                                   |
| Buffalo, NY                     | 1.0                      | .13                              |                              | 9.6                               | 20                                   |
| Columbia, SC <sup>3</sup>       | 0.4                      | .13                              |                              | 12.2                              | 24                                   |
| Columbus, OH                    | 1.3                      | .13                              |                              | 9.6                               | 20                                   |
| Erie, PA                        | 0.3                      | .13                              |                              | 12.2                              | 8                                    |
| Fayetteville, NC                | 0.3                      | .13                              |                              | 12.2                              | 24                                   |
| Johnstown, PA                   | 0.3                      | .13                              |                              | 12.2                              | 24                                   |
| Kansas City, MO-KS              | 1.5                      | .13                              |                              | 8.5                               | 18                                   |
| Lafayette, IN                   | 0.1                      | .13                              |                              | 12.2                              | 24                                   |
| Lake Charles, LA                | 0.2                      | .13                              |                              | 24.3                              | 39                                   |
| Lancaster, PA                   | 0.4                      | .13                              |                              | 12.2                              | 24                                   |
| Lexington, KY                   | 0.3                      | .13                              |                              | 12.2                              | 24                                   |
| Norfolk-Virginia Beach          | 1.3                      | .13                              |                              | 9.6                               | 20                                   |
| Newport News, VA                |                          |                                  |                              |                                   |                                      |

Table A-3.1 (continued)

| Area                                          | Population<br>(millions) | 1986-<br>1988<br>design<br>value | Percent<br>above<br>standard | NMOC/<br>NO <sub>x</sub><br>ratio | Required<br>VOC<br>reductions<br>(%) |
|-----------------------------------------------|--------------------------|----------------------------------|------------------------------|-----------------------------------|--------------------------------------|
| Santa Barbara, San<br>Maria and<br>Lompoc, CA | 0.3                      | .13                              | 8%                           | 12.2                              | 19                                   |
| Scranton and<br>Wilkes-Barre, PA              | 0.7                      | .13                              |                              | 14.3                              | 26                                   |
| Stockton, CA                                  | 0.4                      | .13                              |                              | 12.2                              | 19                                   |
| Tampa, FL                                     | 1.9                      | .13                              |                              | 9.6                               | 20                                   |
| York, PA                                      | 0.4                      | .13                              |                              | 12.2                              | 24                                   |
| Youngstown-Warren,<br>OH                      | 0.5                      | .13                              |                              | 12.2                              | 24                                   |

<sup>1</sup> Transport emissions are included in calculations of required reductions.

<sup>2</sup> Design value based on 1988 data only. NO<sub>x</sub> ratio estimated.

<sup>3</sup> Design value based on 1987 and 1988 data only. NO<sub>x</sub> ratio estimated.

*Source:* Population figures are from EPA, *National Air Quality and Emissions Trends Report, 1987*, Table 4-3. Design values are from the July 27, 1989 EPA *Environmental News*. NMOC/NO<sub>x</sub> ratios and information needed to calculate percentage reductions taken from a personal correspondence from Francis Bunyard, EPA Office of Air Quality Planning and Standards, August 1989.

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